PALEONTOLOGY LIBRARY
Museum Library
QE
781
J8
NOV 3 1940

Volume 14 NOVEMBER, 1940 Number 6

# JOURNAL OF PALEONTOLOGY

*A Publication of*

The Society of Economic Paleontologists and Mineralogists

*A Division of the American Association of Petroleum Geologists*

*and*

The Paleontological Society

*An Associate of the Geological Society of America*

## CONTENTS

Studies of Carboniferous ammonoids: Parts 5-7 ..... *A. K. Miller and W. M. Furnish* 521

Mississippian Inadunata—*Eupachycrinus* and related forms ..... *A. H. Sutton and Virgil D. Winkler* 544

New genus of Foraminifera from the later Tertiary of California ..... *M. L. Natland* 568

Early growth stages of Carboniferous microcrinoids and blastoids ..... *Raymond C. Moore* 572

*Misellina* and *Brevaxina*, new Permian fusulinid Foraminifera ..... *Hubert G. Schenck and M. L. Thompson* 584

Contributions to nautiloid nomenclature ..... *Curt Teichert* 590

Diagrammatic representation of ammonoid sutures ..... *W. M. Furnish and A. G. Unklesbay* 598

REVIEWS ..... 603

CORRECTION ..... 615

NOTICE ..... 615

INDEX ..... 619

EDITORS

C. WYTHE COOKE, for the Paleontological Society.

NORMAN D. NEWELL, for the Society of Economic Paleontologists and Mineralogists.

---

The JOURNAL of PALEONTOLOGY is published bi-monthly. The numbers issued in January, May, and September are sponsored by the Paleontological Society; those issued in March, July, and November are sponsored by the Society of Economic Paleontologists and Mineralogists.

The subscription price of the JOURNAL OF PALEONTOLOGY is $6.00 per year prepaid to addresses in the United States, Mexico, Cuba, Puerto Rico, Panama Canal Zone, Republic of Panama, Dominican Republic, El Salvador, Bolivia, Colombia, Honduras, Nicaragua, Peru, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands.

Single numbers, $2.00 each.

Postage is charged extra: For Canada, 20 cents on annual subscriptions (total $6.20); for all other countries in the Postal Union, 40 cents on annual subscriptions (total $6.40).

The JOURNAL will furnish reprints at cost. Orders should accompany manuscript.

Communications about the JOURNAL, subscriptions, rates, memberships, change of address, and nonreceipt of preceding numbers should be addressed to Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa, Oklahoma. Claims for nonreceipt of preceding numbers must be sent in within three months of the date of publication in order to be filled gratis. Communications in regard to advertising should be addressed to Norman D. Newell, University of Wisconsin, Madison, Wisconsin.

Communications in regard to manuscripts, or purely editorial matters should be addressed to Norman D. Newell, University of Wisconsin, Madison, Wisconsin, or C. Wythe Cooke, U. S. Geological Survey, Washington, D.C.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates normally should be arranged for publication at the size of 5 by 7 inches, exclusive of margins, heading, and title. Printed numerals of standard size and form may be obtained free from either editor. When requesting them state number of plates and the dimensions of each plate.

---

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R., authorized April 3, 1935.

Additional entry as second-class matter at the Post Office at Menasha, Wis.

---

GEORGE BANTA PUBLISHING COMPANY, MENASHA, WIS.

# JOURNAL OF PALEONTOLOGY

*A Publication of* THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS, *A Division of the American Association of Petroleum Geologists and* THE PALEONTOLOGICAL SOCIETY, *An Associate of the Geological Society of America*

VOLUME 14 NOVEMBER, 1940 NUMBER 6

## STUDIES OF CARBONIFEROUS AMMONOIDS: PARTS 5–7

A. K. MILLER AND W. M. FURNISH
State University of Iowa, Iowa City, Iowa, and Oklahoma A. and M. College, Stillwater, Oklahoma

ABSTRACT—In part five the genera *Paralegoceras* and *Pseudoparalegoceras* of the Lower Pennsylvanian are restudied. The name *Diaboloceras* (genotype, *D. varicostatum*, n. sp.) is proposed for intermediate forms from Oklahoma and Texas; and the occurrence of triangular coiling in this group is discussed. Also, the genus *Dunbarites* is established for *Paralegoceras rectilaterale* Miller of the Gaptank formation of west Texas.

Part six deals with representatives of *Prouddenites*, *Schistoceras*, and *Eoasianites*, which are illustrated and described from the middle part of the Missouri series at Kansas City, Missouri. Most of the specimens are from nodules in the Muncie Creek shale member of the Iola formation. The occurrence of *Prouddenites* is discussed, and two new varietal names are proposed.

In part seven *Eoasianites merriami*, n. sp., is illustrated and described from the Upper Mills Ranch inlier of Crook County, Oregon.

### V. THE PENNSYLVANIAN AMMONOID GENUS PARALEGOCERAS AND RELATED FORMS

PARALEGOCERAS is a distinctive form that occurs widespread in the Lower Pennsylvanian of the Mid-Continent region. The genus was established by Hyatt in 1884, and since that time numerous species have been referred to it. Nevertheless, the genus has never been carefully delimited or correctly interpreted, largely because of insufficient knowledge in regard to its genoholotype. However, the type specimen on which the type species is based was loaned to us for study by Prof. A. H. Sutton, and it is moderately well preserved though somewhat crushed laterally. This holotype elucidates most of the significant characters of the genus. A detailed study of this important specimen, together with closely related forms, has yielded a practicable understanding of the genus.

#### Genus PARALEGOCERAS Hyatt, 1884

Conch subdiscoidal and large, attaining a diameter of as much as 150 mm. Umbilicus moderately large. Lateral zones of conch bear prominent transverse ribs or nodes during adolescence. Early volutions of conch triangularly coiled. Sutures form a total of 10 lobes, five of which are external in position whereas five are internal. Ventral lobe is very prominently subdivided, but all the rest are simple and pointed.

The triangular coiling of the early volutions of the conch is perhaps the most unusual feature of this genus. A somewhat similar coiling has been found to be characteristic of three groups of the Devonian clymenids (Schindewolf, 1937). Of these, *Soliclymenia paradoxa* (Münster) bears a striking resemblance to immature representatives of *Paralegoceras*. Schindewolf has found that in the clymenids, at first, the tendency toward triangular coiling af-

fects only the innermost volutions of the conch, but in more advanced forms additional volutions become triangularly coiled. In the Pennsylvanian specimens which we are studying, only the inner volutions are strongly triangular, and in the outer volutions, the coiling gradually becomes regular. At least incipient triangular coiling, comparable to that shown by *Soliclymenia semiparadoxa* Schindewolf, is clearly discernible in immature representatives of *Gastrioceras branneri* Smith in our collections from the basal Pennsylvanian of Arkansas, and the same is true of the closely similar Chinese specimens illustrated by Yin (1935, pl. 4, figs. 1a, 2). This trend toward triangular coiling in the Pennsylvanian gastrioceratids culminated in *Paralegoceras*.

*Diaboloceras*, which is intermediate between *Gastrioceras* and *Paralegoceras*, is represented in our collections from the Atoka of Oklahoma by a single specimen showing moderately developed triangular coiling of the early volutions. In the outer volutions of *Soliclymenia paradoxa* the angularity of the whorls becomes somewhat less pronounced, and in slightly larger representatives of *Paralegoceras* the coiling of the whorls becomes regular. Triangularly coiled clymenids have been found in the Devonian at several rather widely separated localities in Europe, and in the Pennsylvanian comparable representatives of *Paralegoceras* are known from Iowa, Arkansas, Oklahoma, and Texas in the United States and from Slovakia in central Europe. It should, of course, be understood that the clymenids became extinct at the end of the Devonian and are not related to *Paralegoceras;* the development of triangular coiling in the two stocks is merely a remarkable case of parallel development. Comparable adolescent triangular coiling has been observed by Spath in some representatives of *Schloenbachia* of the Cretaceous. Several paleontologists, for example, Frech, Croneis, Plummer and Scott, and Schindewolf, have speculated as to the significance of the triangular coiling. Since, in some cases, this coiling is limited to the inner volutions of the conch, it might be assumed that the ancestors of these forms were triangular at maturity. However, as emphasized by Schindewolf, the triangularity is in no case known to be limited to the outer volutions of the conch, and it becomes more pronounced in advanced forms. It therefore seems that *Paralegoceras* may have prominently triangular descendants but not ancestors. This conclusion is quite in accord with the principles of proterogenesis, outlined by Spath and Schindewolf, which postulate that, in some cases, advanced characters first appear during adolescence and then gradually encroach on the mature stages. This theory has been well illustrated in the group of *Macrocephalites* of the Jurassic. It seems to be well founded insofar as *Paralegoceras* is concerned, but that form is an exception among Paleozoic ammonoids to which the recapitulatory principle generally is applicable.

We are eliminating from *Paralegoceras* all of the North American forms that have been referred to it except the genotype and *Goniatites texanus* Shumard (and synonyms). In both of these species the early volutions of the conch are prominently nodose and are triangularly coiled, but in *P. texanum* at maturity the umbilicus is larger and the ornamentation is stronger than in the genotype. *P. texanum* is the genotype of *Bendoceras*, which we regard as a synonym of *Paralegoceras*. The sutures of *Paralegoceras* form one more pair of lobes than do those of *Pseudoparalegoceras* and two less pairs than do those of the related genus *Schistoceras*. The Permian genus *Metalegoceras*, which is superficially similar to *Paralegoceras*, but which developed directly from *Eoasianites*, has sutures that form one more pair of lobes than do those of *Paralegoceras*. The available data in regard to *Pintoceras* are perhaps insufficient to differentiate it from *Paralegoceras;* however, the only known specimen belonging in that genus, which has not been illustrated or described in detail, came from a higher horizon in the Pennsylvanian than any form known to be referable to *Paralegoceras*. The affinities of *Paralegoceras discus* Smith, which is of intermediate stratigraphic position, are very uncertain. *Diaboloceras* and *Dunbarites*, which resemble *Paralegoceras* in certain respects, are described in detail below.

Both of the American species now defi-

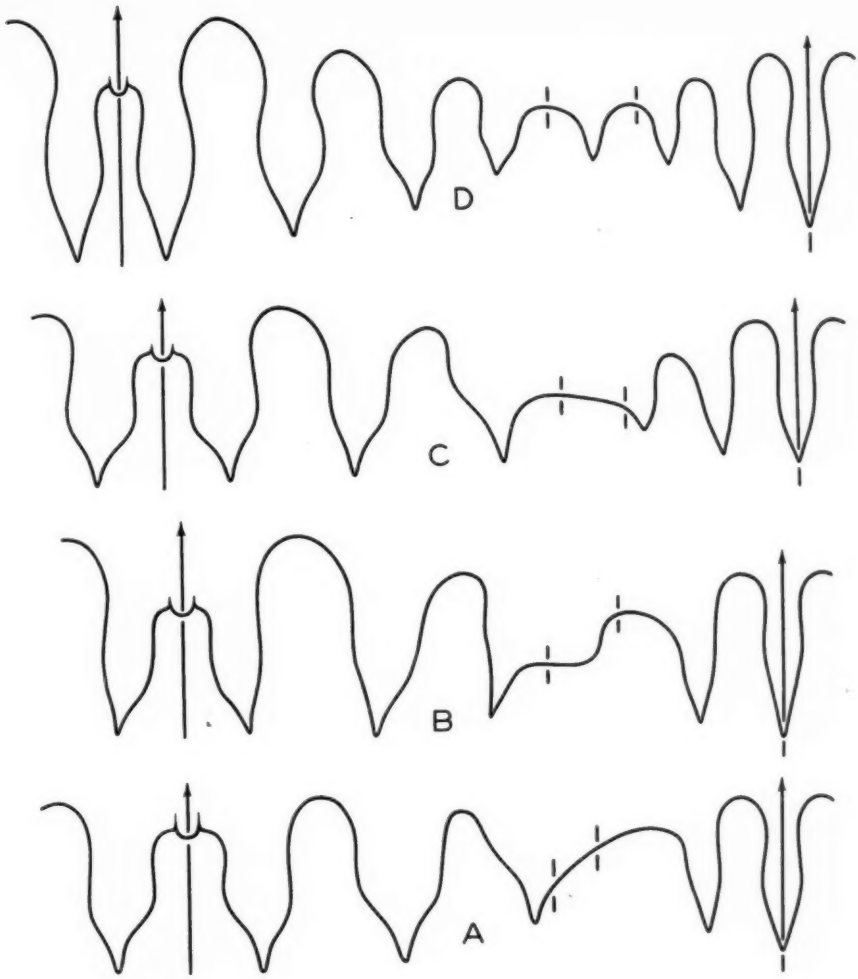



FIG. 1.—Mature sutures of the genotypes of *Pseudoparalegoceras*, *Diaboloceras*, *Paralegoceras*, and *Schistoceras*.

(A) *Pseudoparalegoceras russiense* (Tzwetaev), ×1; based on a specimen from the Moscovian of the Moscow area, U.S.S.R. Adapted from Karpinsky.

(B) *Diaboloceras varicostatum* Miller and Furnish, n. sp., at a diameter of some 55 mm., ×2½; based on a syntype (pl. 63, figs. 8–10) from the Magdalena formation of the Sierra Diablo, Culberson County, Texas.

(C) *Paralegoceras iowense* (Meek and Worthen) at a diameter of about 80 mm., ×1½; based on the holotype from the Cherokee formation of Wapello County, Iowa. Details of internal sutures in part restored.

(D) *Schistoceras hyatti* Smith at a diameter of about 50 mm., ×2; based on specimens from the Graham formation of Jack County, Texas (John Britts Owen collection at State University of Iowa, 14000).

nitely referred to *Paralegoceras* occur in the lower Atoka of Arkansas and Oklahoma and in the Smithwick of north-central Texas. Also, a single representative of *P. iowense*, the holotype, has been found in the lower Cherokee of southern Iowa. In all four of these states the containing beds appear to be of about the same age. *Paralegoceras discus* Smith, from a somewhat higher horizon, the Buckhorn asphalt is so poorly known that we are uncertain in regard to its generic affinities. A cephalopod fauna similar to that of the Atoka and the Smithwick, is known from the Amotape Mountains of northwestern Peru; some of the forms obtained there may belong in *Paralegoceras*, but their affinities can not be determined with certainty from the published data. Also, the specimen from the "Westphalien" of northwestern Africa which Menchikoff (1930, p. 199, pl. 16, figs. 3a, 3b) illustrated and described as "*Gastrioceras* sp." probably belongs in *Paralegoceras*. Plummer and Scott's figure 14 on their plate 19 of 1937 is a typical *Paralegoceras* suture and is stated to be based on a specimen of some 24 mm. diameter from the Graham formation of north-central Texas. This illustration can be said to indicate that *Paralegoceras* may occur in the Graham, but we think that it probably was based on a worn specimen of *Schistoceras*.

### PARALEGOCERAS IOWENSE
### (Meek and Worthen)
### Plate 62, figures 1–3

*Goniatites iowensis* MEEK and WORTHEN, *1860*, Acad. Nat. Sci. Philadelphia, Proc., 1860, p. 471; *1866*, Illinois Geol. Survey, vol. 2, pp. 392–393, pl. 30, figs. 3a–3c.

*Paralegoceras iowense* HYATT, *1884*, Boston Soc. Nat. History Proc., vol. 22, p. 327; SMITH, *1896*, Am. Philos. Soc., Proc., vol. 35, pp. 263–265, pl. 19, figs. 1–3b; SMITH, *1903* [part], U. S. Geol. Survey, Mon. 42, pp. 100–101, pl. 4, figs. 12–14 [not pl. 9, figs. 4–7]; GIRTY, *1919* [part], Am. Assoc. Petroleum Geologists, Bull., vol. 3, p. 72; SELLARDS, *1932*, Texas Geol. Survey, Bull. 3232, pl. 6, figs. 17, 18; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 195, 198, 199–200, 211, pl. 18, figs. 8, 9.

*Paralegoceras newsomi* SMITH, *1904*, U. S. Geol. Survey, Mon. 42, pp. 101–104, pl. 12, figs. 4–9.

*Paralegoceras* sp. CRONEIS, *1930* [part], Science, n. ser., vol. 72, p. 534; (?) PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 212.

*Bendoceras texanum* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701, pp. 210–215 [not pl. 12, figs. 1–7].

This species was based on a single specimen, which is the only American representative of the genus known from areas north of Oklahoma. This specimen is crushed laterally, but it elucidates most of the significant characters of the genus and species. The illustrated side of the specimen is moderately well preserved and only slightly crushed, but the other side is greatly crushed and for the most part is not removed from the matrix. The previously published diagrammatic ventral outline of this specimen is based on the present shape of the illustrated side of the conch and is probably much too narrow. The specimen is septate throughout and, perhaps in its extreme adoral portion, represents phragmacone. Its maximum diameter measures about 107 mm.

Portions of the test preserved on the holotype show that at least the outer one and one-third volutions of that specimen are devoid of prominent ornamentation. Meek and Worthen's published drawing of this specimen shows about two and one-half volutions exposed in the umbilicus, but as a matter of fact, only about one and one-third volutions are visible. Furthermore, the crushing that the specimen has undergone has caused the exposed portion of the penultimate whorl to appear wider than it was originally. A pyritized fragment

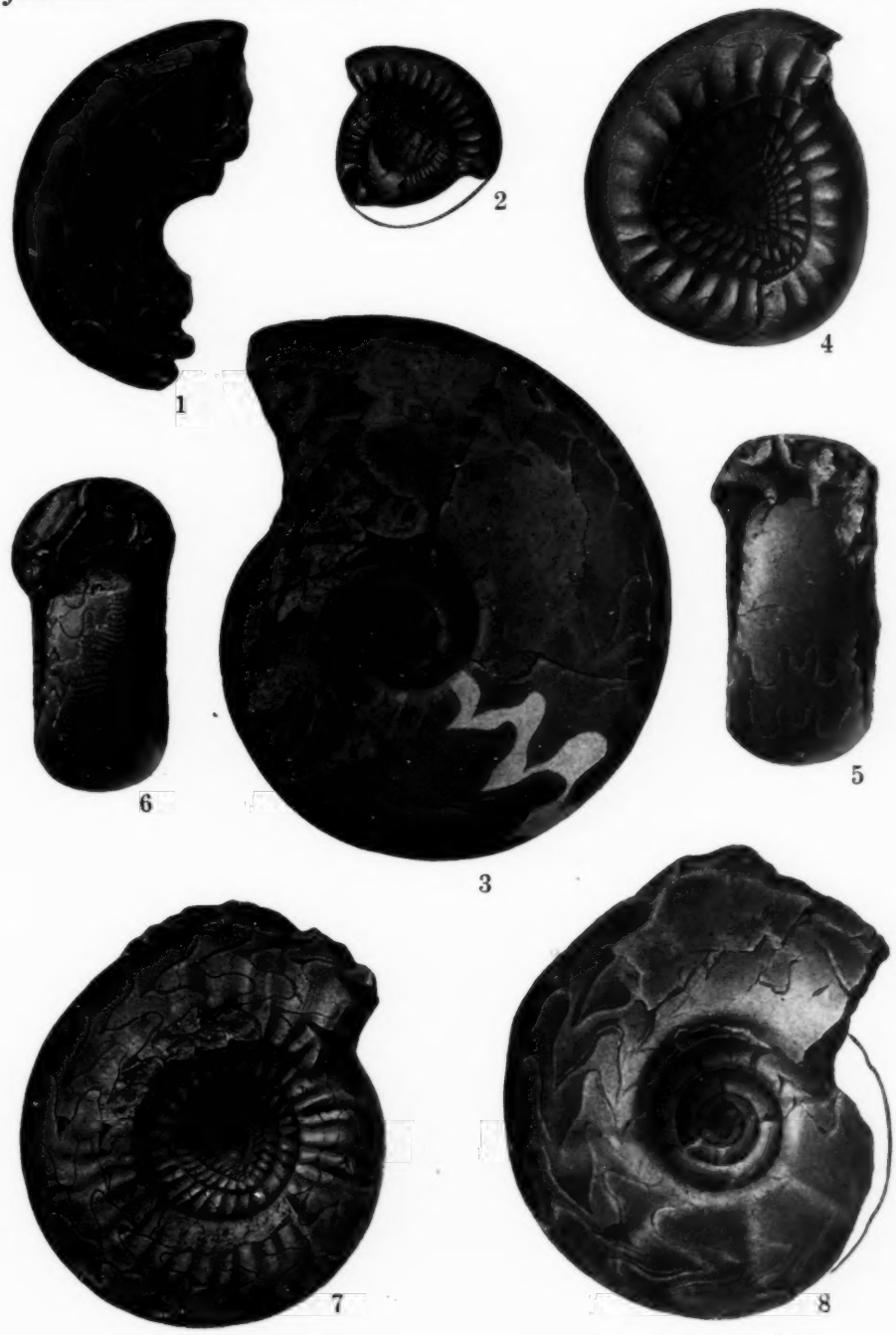
---

EXPLANATION OF PLATE 62

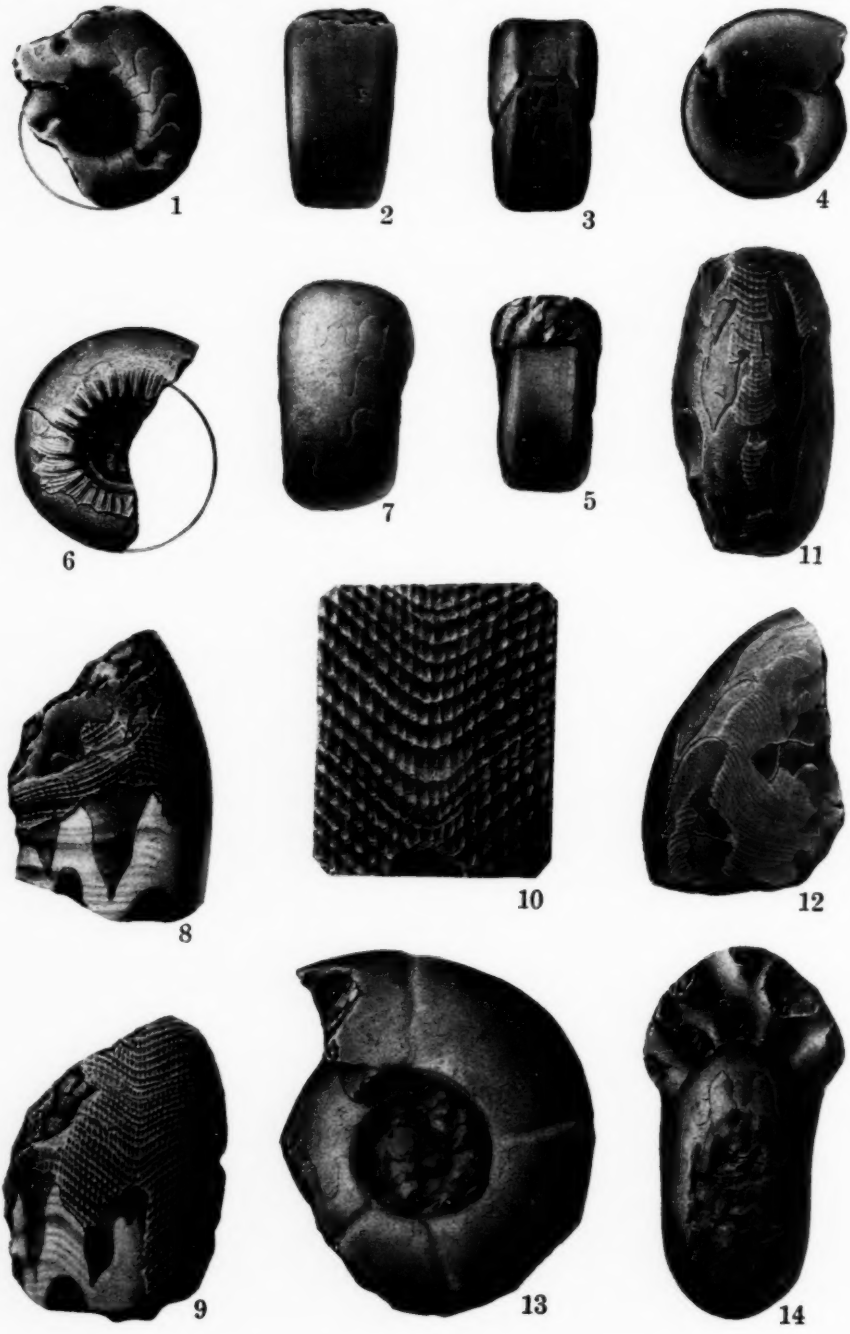
FIGS. *1–3*—*Paralegoceras iowense* (Meek and Worthen). *1*, Lateral view, ×1, of a mature specimen; *2*, Lateral view, ×2, of an immature specimen, both from the Smithwick shale near Rochelle, Texas; *3*, Lateral view, ×¾, of the holotype, from the Cherokee of Wapello County, Iowa. (p. 524)

*4–7*—*Paralegoceras texanum* (Shumard). *4*, *5*, Two views, ×2, of a moderate-sized specimen; *6*, Ventral view, ×1½, of a testiferous specimen; *7*, Lateral view, ×1, of a mature individual; all from the lower Atoka formation near Clarita, Oklahoma. (p. 526)

*8*—*Pseudoparalegoceras brazoense* Plummer and Scott. Lateral view, ×¾, of a well-preserved specimen from the Magdalena formation near Rowe, New Mexico. (p. 529)




Miller and Furnish, Carboniferous Ammonoids




Miller and Furnish, Carboniferous Ammonoids

of a whorl, representing about half of a volution of the conch at a diameter of about 4 mm., is preserved near the center of the umbilicus. It shows clearly that the inner whorls are triangularly coiled and are marked by prominent ornamentation, which consists of umbilical nodes or ribs on the internal mold. The fragment under consideration is insufficient to elucidate the precise nature of the inner whorls, but it shows conclusively that they are like those of well-preserved congeneric forms known from Arkansas, Oklahoma, and Texas.

The illustrations of sutures of the holotype which have been published previously are not accurate in detail. As shown by text figure 1, near the midlength of the outer volution of the holotype, each suture consists of a total of 10 lobes, only one of which (the ventral lobe) is divided. The subdivisions of the ventral lobe are of about the same size as the first lateral lobes. The second lateral lobes are located on the flanks of the conch ventrad of the umbilical shoulders. The dorsal lobe and the first lateral lobes of the internal sutures are deep and narrow. The second lateral lobes of the internal sutures are located dorsad of the umbilical seams. The lobes which Plummer and Scott thought they observed on the umbilical walls do not exist.

*Remarks.*—Insofar as we have been able to ascertain, the holotype of this species can not be differentiated specifically from specimens that occur in the Atoka of Arkansas and Oklahoma and in the Smithwick of north-central Texas. The Atoka and the Smithwick carry in addition similar forms that can be differentiated only by their wider umbilicus and stronger ornamentation. In both of these formations there is more or less gradation between these two types of shells. Nevertheless, the two types appear to differ sufficiently to be regarded as distinct species, and we are retaining the name *Paralegoceras texanum* (Shumard) for the widely umbilicated strongly ornamented forms. The features that characterize *P. texanum* are relatively primitive, but apparently there is no chronological difference between *P. texanum* and *P. iowense*. The only other congeneric form known is *P. nopcsai* (Rakusz) of the upper Namurian of Slovakia, and it resembles *P. texanum* more closely than *P. iowense*.

*Occurrence.*—The holotype of this species was collected over 80 years ago near Alpine, an abandoned town in Wapello County, south of Ottumwa, Iowa, probably from the lower Cherokee. J. P. Smith has figured from the lower Atoka near Morrillton, Conway County, Arkansas, a specimen which exhibits the characteristics of this species as interpreted by us. Although Smith made this specimen the type of a new species, *Paralegoceras newsomi*, he first regarded it as referable to *P. iowense*, and later stated that it differed from that species only in the shape of its conch. Also, we have a conspecific specimen from the lower Atoka just north of Clarita, Oklahoma (sec. 2, T. 1 S., R. 8 E.), and at least two specimens that can be referred to this species from the Smithwick shale about 3½ miles east of Rochelle, McCulloch County, Texas. Furthermore, it seems likely that in this species belong some of the specimens that Croneis studied from the Atoka of Arkansas and Oklahoma and some of those that Plummer and Scott studied from the Smithwick of north-central Texas.

*Types.*—University of Illinois, 11098 (holotype); State University of Iowa, 1414 (pl. 62, figs. 1, 2); and John Britts Owen

EXPLANATION OF PLATE 63

FIGS. *1–5—Dunbarites rectilateralis* (Miller). *1, 2*, Lateral and ventral views, ×3, of a syntype; *3–5*, Three views, ×3, of the other syntype; both from the upper Gaptank formation in the Glass Mountain region of west Texas. (p. 532)

*6–10—Diaboloceras varicostatum* Miller and Furnish, n. sp. *6, 7*, Lateral and ventral views, ×2¼, of a small specimen; *8–10*, Lateral and ventral views, ×1½, and enlarged view of surface ornamentation, ×4, of another syntype; both from the Smithwick horizon in the Magdalena formation near the eastern margin of the Sierra Diablo of west Texas. (p. 527)

*11, 12—Pseudoparalegoceras bellilineatum* Miller and Furnish, n. sp. Ventral and lateral views, ×1, of the largest of the syntypes; from the same horizon and locality as the preceding. (p. 531)

*13, 14—Pseudoparalegoceras brazoense* Plummer and Scott. Lateral and ventral views, ×¾, of a specimen from the Boggy formation east of Ada, Oklahoma. (p. 529)

collection at State University of Iowa, 13999.

PARALEGOCERAS TEXANUM (Shumard)
Plate 62, figures 4–7

*Goniatites texanus* SHUMARD, *1863*, St. Louis Acad. Sci., Trans., vol. 2, p. 109.
*Paralegoceras iowense* HYATT, *1893*, Texas Geol. Survey, Ann. Rept. 4, p. 474; SMITH, *1903* [part], U. S. Geol. Survey, Mon. 42, pp. 100–101, pl. 9, figs. 4–7 [not pl. 4, figs. 12–14]; GIRTY, *1919* [part], Am. Assoc. Petroleum Geologists, Bull., vol. 3, p. 72.
*Paralegoceras texanum* SMITH, *1903*, U. S. Geol. Survey, Mon. 42, p. 104.
*Paralegoceras* n. sp. PLUMMER and MOORE, *1921*, Texas Univ. Bull. 2132, p. 58.
*Paralegoceras* sp. PLUMMER and MOORE, *1921*, Texas Univ. Bull. 2132, p. 58; CRONEIS, *1930* [part], Science, n. ser., vol. 72, p. 534; (?) PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 212.
*Bendoceras texanum* PLUMMER and SCOTT, *1937* [part?], Texas Univ. Bull. 3701, pp. 15, 29, 30, 33, 209, 210–215, pl. 12, figs. 1–7.
*Bendoceras shumardi* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701, pp. 15, 209, 215–216, pl. 11, figs. 10–12 [not 8, 9].
*Bendoceras moorei* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701, pp. 15, 33, 209, 216–217, pl. 11, figs. 14–16.
*Paralegoceras hyatti* MOORE [in PLUMMER and SCOTT], *1937*, Texas Univ. Bull. 3701, p. 210.
*Bendoceras* n. sp. PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 213, pl. 12, fig. 8.

The holotype of this species, which was never figured, has probably been lost. Plummer and Scott's neoholotype resembles typical *P. iowense* but differs particularly in that it has a large umbilicus and prominent ornamentation in the form of umbilical ribs. We have not been able to distinguish small representatives of these two species. However, in specimens of a diameter of some 50–100 mm., the diameter of the umbilicus in *P. iowense* is about one-fourth that of the conch, whereas in *P. texanum* it is about two-fifths. Apparently, the conch of *P. texanum* bears umbilical ribs throughout ontogenetic development, though these gradually become somewhat less prominent on the adoral portion of large individuals. In *P. iowense* comparable ribs are present during early adolescence, but they are lost as the conch approaches maturity. The available information in regard to the size of the conch, at which the ribs are lost in *P. iowense*, is not very satisfactory, but it can be stated that in the holotype they disappear after the diameter of the conch is more than 4 mm. and before it is as much as 45 mm. In the specimen represented by figure 1 on plate 62, in another figured by J. P. Smith as *P. newsomi*, and in a conspecific specimen in our collections from the lower Atoka near Clarita, Oklahoma, these ribs are lost after the diameter of the conch is more than 20 mm. and before it is 40 mm.

During early adolescence the conch is strongly evolute, and the development of the sutures resembles that in the genus *Gastrioceras*. As shown by text figure 2A, at a diameter of some 8 mm. a *Gastrioceras* stage of development is attained. By the time the conch has become some 15 mm. in diameter a pair of incipient lobes has been developed on the umbilical seams and the sutures resemble those of *Diaboloceras* (text figure 2B).

*Bendoceras shumardi* Plummer and Scott and *B. moorei* Plummer and Scott appear, in each case, to have been based on singularly poor specimens. The published illustrations of *B. shumardi* indicate that that form cannot be distinguished from *Paralegoceras texanum*. Plummer and Scott's suture drawing of the holotype of "*B. shumardi*" does not show "an extra lobe and an extra saddle . . . near or on the umbilical shoulders," which is alleged to be the distinguishing character of their new species; on the contrary, the suture is represented as having the same number of elements as does that of *P. texanum*. The only known representative of "*B. moorei*" is shown by the published illustrations to be badly crushed. Plummer and Scott's diagrammatic representation of its sutures is indeed unique but suggests that it is based on the ventral portion of the penultimate volution and the lateral portion of the ultimate volution. Plummer and Scott state that the "sculpture and appearance" of this holotype are similar to those of *P. texanum*, and if our belief in regard to their interpretation of the sutures is correct, the two are conspecific.

*Occurrence.*—All of the specimens that have been illustrated and described previously as representing this species, including the holotype and the neoholotype, came from the Smithwick shale near Bend, San Saba County, Texas. We are also referring

to it the holotypes of *Bendoceras moorei* and *B. shumardi*, which came from the Smithwick about 3½ miles east of Rochelle, McCulloch County, Texas. In addition, we have numerous conspecific specimens from the lower Atoka near Clarita, Oklahoma, and from about 3 miles southeast of Jessie, Oklahoma.

The specimen from the lower Atoka near Fayetteville, Arkansas, which in 1937 Plummer and Scott (pl. 12, fig. 8) illustrated as *Bendoceras* n. sp., is probably referable to this species. Finally, we have an immature specimen that probably represents this species from the same general horizon in a black shale about 4850 feet below the surface in sec. 27, T. 2 N., R. 8 E., Coal County, Oklahoma.

*Hypotypes.*—John Britts Owen collection at State University of Iowa, 13996–13998 (pl. 62, figs. 4–7), 13994, 13995.

### Genus DIABOLOCERAS
### Miller and Furnish, n. gen.

This genus is being established for forms that resemble typical *Paralegoceras* rather closely, but have somewhat more primitive sutures. In *Paralegoceras*, each suture forms a total of 10 lobes, whereas in *Diaboloceras* each forms only eight lobes, though there is in addition an incipient pair on the umbilical wall. Furthermore in *Paralegoceras*, the inner volutions of the conch show prominent triangular coiling, and the ornamentation of the test becomes less conspicuous at maturity. It should, however, be emphasized that *Diaboloceras* and *Paralegoceras* resemble each other so closely that unless the umbilical portions of the sutures are known, specimens of moderate size can not be distinguished. It would therefore seem justifiable to consider *Diaboloceras* as a subgenus of *Paralegoceras*, and we would employ it as such except for the cumbersome terminology involved.

Externally *Diaboloceras* resembles *Gastrioceras branneri* Smith and its affines, but these forms have only typical gastrioceratid sutures; that is, they lack the characteristic incipient lobes of *Diaboloceras*. The general form of the conch in *Pseudoparalegoceras* also is similar, but representatives of that genus lack the incipient lobes of the sutures, the prominent ornamentation at maturity, and a semblance of triangular coiling during adolescence.

The only species that we are definitely referring to this genus is the genotype, *D. varicostatum*, which is known from the Smithwick horizon of the Magdalena in west Texas and from the Coody sandstone member of the lower Atoka in eastern Oklahoma. However, the ornamentation of *Gastrioceras pacificum* Thomas and *G.?* sp. (Thomas, 1928, pl. 11, fig. 2, 2a) of northwestern Peru suggests that they also belong in *Diaboloceras*. It seems probable that Thomas' diagrammatic representation of the umbilical portion of the sutures of *G. pacificum* is not precisely accurate.

### DIABOLOCERAS VARICOSTATUM
### Miller and Furnish, n. sp.
### Plate 63, figures 6–10

*Bendoceras texanum* PLUMMER, *1932*, Am. Assoc. Petroleum Geologists, Bull., vol. 16, p. 486.
*Bendoceras shumardi* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701, pp. 215–216, pl. 11, figs. 8, 9 [not 10–12].
*Bendoceras moorei* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701 pp. 216–217 [not pl. 11, figs. 14–16].

Conch large, and phragmacone attains a diameter of at least 175 mm. A mature fragment in our collections is about 40 mm. high and 45 mm. wide. Umbilicus also large. One nearly complete specimen shows a triangularly coiled umbilicus during adolescence; however, the feature is not well developed, and the species seems to be intermediate between *Paralegoceras* and some representatives of *Gastrioceras* in this respect.

Surface of test is prominently reticulate as it bears both longitudinal and transverse lirae. Also during adolescence the umbilical zones bear prominent transverse ribs. We have a small specimen some 4½ mm. in diameter which is strongly ribbed and evolute. At full maturity the lateral ribs become less pronounced but form prominent nodes on the umbilical shoulders. During adolescence the growth-lines develop slight ventral sinuses which become much more prominent and almost subangular at maturity. At full maturity slight lateral sinuses are also developed.

The shape of the sutures is shown by text figure 1B. It should be noted that the

prongs of the ventral lobe are much narrower than the first lateral lobes. The umbilical lobe is slightly but distinctly outside the umbilical shoulder, and an incipient adventitious lobe is developed at maturity on the umbilical wall.

*Remarks.*—The characteristic features of this species are its ornamentation and its sutures. The prominent ornamentation is

*smithwickense* Plummer and Scott may be closely related to the species under consideration. The figured specimens are fairly small and fragmentary, but the whorls are relatively low and broad.

*Occurrence.*—The syntypes came from the Smithwick horizon in the Magdalena formation below the Permian Hueco conglomerate at the base of the escarpment

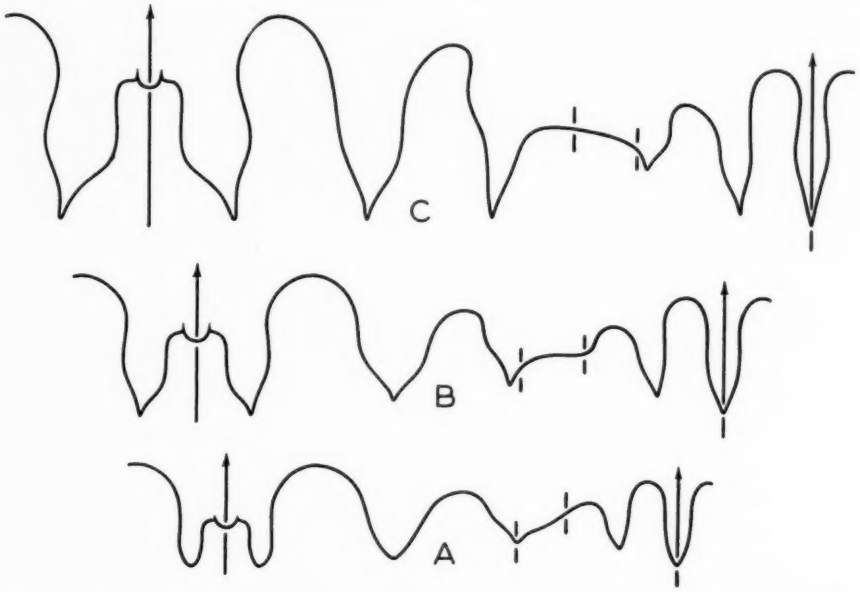



FIG. 2.—Sutures of *Paralegoceras texanum* (Shumard) during ontogenetic development (A), *Gastrioceras* stage, at a diameter of about 8 mm., ×12. (B), *Diaboloceras* stage, at a diameter of about 15 mm., ×7. (C), Full maturity, at a diameter of about 60 mm., ×3; same specimen as pl. 62, fig. 7.

Based on three specimens from the Atoka formation near Clarita, Oklahoma (John Britts Owen collection at State University of Iowa, 13995, 13998).

retained even during late maturity. The sutures are unique in that they form incipient lobes on the umbilical walls; the sutures of *Paralegoceras texanum* pass through a similar stage at some 15 mm. diameter. However in that species the incipient lobes appear on the umbilical seams rather than outside of them. The position of the lobes in simple sutures of this type is determined to a large extent by the shape of the conch.

*Diaboloceras? pacificum* of northwestern Peru appears to be very similar to *D. varicostatum* but its sutures as figured by Thomas differ appreciably. *Gastrioceras*

about ¼ mile north of the outer Marble Canyon intrusion in the Sierra Diablo of Culberson County, Texas. We have conspecific specimens from the Coody sandstone member of the lower Atoka near the top of Braggs Mountain south of Ft. Gibson and southeast of Muskogee, Oklahoma. Numerous representatives of this species have been collected from the Sierra Diablo but no associated forms referable to *Paralegoceras* are known. It therefore seems probable that the specimens identified by Plummer and Scott from this locality as *Bendoceras shumardi* and *B. moorei* are actually conspecific with *Diaboloceras vari-*

*costatum*. The holotypes of both of those "species" are from north-central Texas.

*Syntypes*.—State University of Iowa, 1415 (pl. 2, figs. 6, 7), 1416 (pl. 63, figs. 8–10), 1417.

### Genus PSEUDOPARALEGOCERAS Miller, 1934

Conch large and at maturity is subdiscoidal. Umbilicus large. Ornamentation consists of growth lines and in some cases faint longitudinal lirae on the ventral portion of the conch. Also, the internal mold shows prominent transverse constrictions, which form deep ventral sinuses. Sutures form a total of eight lobes, one of which, the ventral lobe, is bifid. All of the lobes are pointed and the subdivisions of the ventral lobe are of the same general size as the first lateral lobes.

The umbilical lobe lies outside the umbilical shoulder, on the umbilical shoulder, or on the umbilical walls. The exact position of this lobe is largely a factor of the shape of the conch. In typical species, this lobe assumes a position outside the umbilical shoulder only after the conch has attained a fairly large size. In the specimen represented by figure 8 on plate 1, this lobe does not migrate to a position outside the umbilical shoulder until the conch has attained a diameter of some 35 mm. In the genotype of *Phaneroceras*, the umbilical lobe does not assume a position on the lateral portion of the conch even during late maturity. In gastrioceratids of this general type, the number of sutural elements is stable, but the shape of the conch is quite variable. Even major changes in the shape of the conch affect only the position and not the number of the sutural elements. A very similar relationship has been observed in the paraceltitids of the Permian and the lecanitids of the Triassic, in which a simple stabilized suture persists with only the position of the lobes being affected by changes in the shape of the conch. Typical *Phaneroceras* and typical *Pseudoparalegoceras* occur in association, and only fully mature representatives of them can be distinguished. Furthermore, the differences between them are not of fundamental importance and, therefore, we are suppressing *Phaneroceras* as a synonym of *Pseudoparalegoceras*, which has priority. *Eoparalegoceras* Delepine is, as its author noted, very close to *Pseudoparalegoceras*, and we are inclined to believe that it should not be differentiated. *Strawnoceras* Plummer and Scott, which was inadvertently introduced as a *nomen nudum* in 1935 (Texas Univ. Bull. 3534, p. 20) is also a synonym of *Pseudoparalegoceras*. Typical *Gastrioceras* can be distinguished from *Pseudoparalegoceras* by its relatively low and broad whorls and by the prominent ornamentation of its conch. The group of *Gastrioceras branneri*, which includes such forms as *G. rurae* Schmidt and *G. reticulatum* Yin, resembles *Pseudoparalegoceras* insofar as the shape of the conch is concerned, but possesses the prominently ornamented test of *Gastrioceras*. In this group the subdivisions of the ventral lobe are relatively narrow as in *Diaboloceras*. It seems probable that *Paralegoceras* developed directly from *Gastrioceras* through *Diaboloceras* rather than from *Pseudoparalegoceras*.

Representatives of this genus are known from the Moscovian (Lower Pennsylvanian) near Podolsk, south of Moscow, U. S. S. R.; the "Westphalien" of the Kenadza Basin in Northwestern Africa; the Lower Pennsylvanian of the Amotape Mountains of northwestern Peru; the Morrow, Atoka, and Boggy formations of the Oklahoma-Arkansas region; the Marble Falls, Smithwick, and lower Millsap Lake of north-central Texas; and the Smithwick horizon of the Magdalena of west Texas and central New Mexico.

### PSEUDOPARALEGOCERAS BRAZOENSE Plummer and Scott

Plate 62, figure 8; plate 63, figures 13, 14

*Strawnoceras brazoense* PLUMMER and SCOTT, *nomen nudum, 1935*, Texas Univ. Bull. 3534, p. 20.

*Pseudoparalegoceras brazoense* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 15, 16, 192, 196–197, pl. 10, figs. 10–14.

Plummer and Scott based this species on poorly preserved specimens, some of which attained a very large size. The umbilicus is moderately large and is equal to about two-fifths the diameter of the specimen. The original types are all internal molds

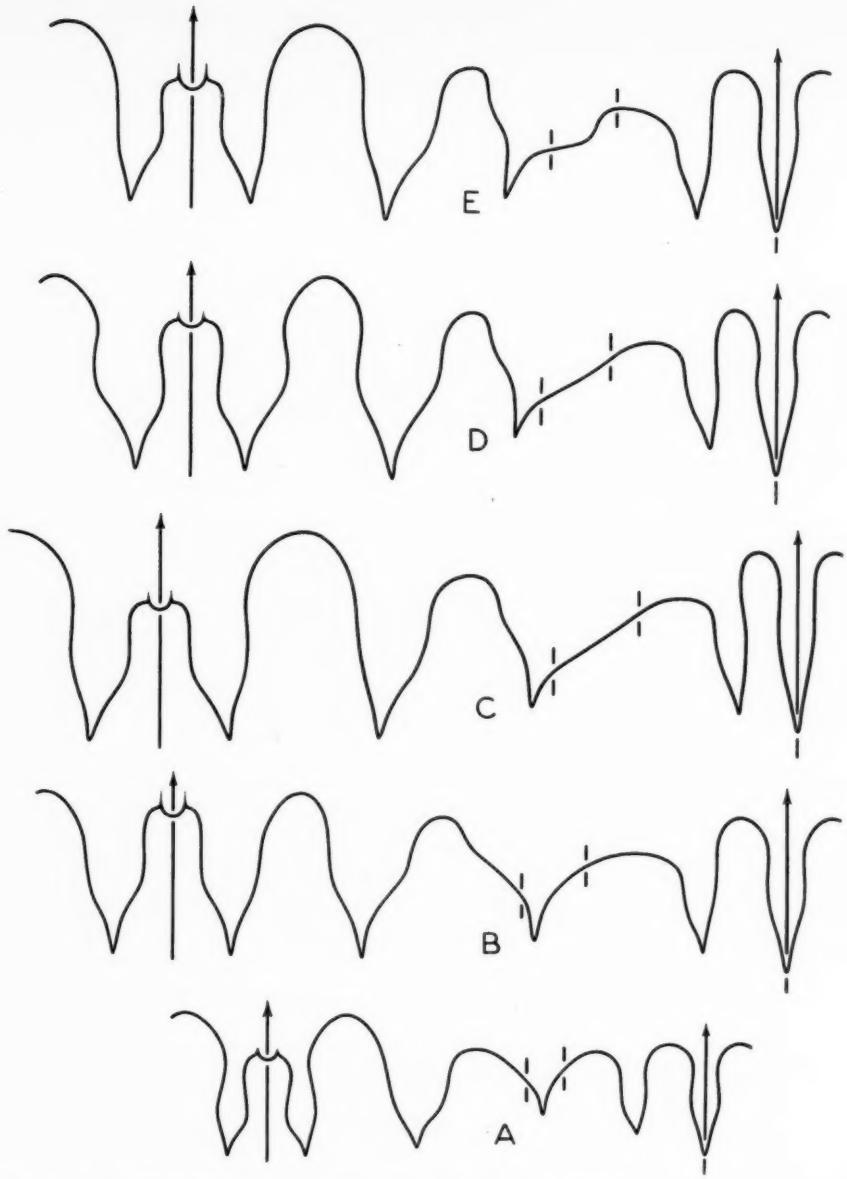



FIG. 3.—Sutures of *Gastrioceras*, *Pseudoparalegoceras*, and *Diaboloceras*.

(A) *Gastrioceras branneri* Smith at a diameter of about 60 mm., ×2; based on a specimen from the Hale sandstone southwest of Harrison, Arkansas (State University of Iowa, 1975).

(B) *Pseudoparalegoceras compressum* (Hyatt) at a diameter of about 50 mm., ×2½ based on a specimen from the Atoka formation near Winslow, Arkansas (John Britts Owen collection at State University of Iowa, 13991).

(C) *Pseudoparalegoceras bellilineatum* Miller and Furnish, n. sp., at a diameter of about 60 mm., ×1½; based on a syntype from the Magdalena formation of the Sierra Diablo, Culberson County, Texas; same specimen as pl. 63, figs. 11, 12.

(D) *Pseudoparalegoceras brazoense* Plummer and Scott at a diameter of about 75 mm., ×1½; based on a specimen from the Magdalena formation of San Miguel County, New Mexico; same specimen as pl. 62, fig. 8.

(E) *Diaboloceras varicostatum* Miller and Furnish, n. sp., at a diameter of about 50 mm.,×3; based on a specimen from the lower Atoka formation on Braggs Mountain southeast of Muskogee, Oklahoma (State University of Iowa, 1418).

which have transverse constrictions that form a prominent ventral sinus.

We have two specimens that appear to be referable to this species. One of them, which came from the Boggy formation of Oklahoma, is the internal mold of the phragmacone of a mature individual. All of its characters coincide with those of the original types. The second specimen that we are referring to this species came from the Magdalena formation of New Mexico. It is a well-preserved internal mold, which is septate throughout. One side of it is largely eroded away, and therefore the width of the conch can not be determined. Small fragments of the test adhering to this specimen show that the growth lines are rather faint, and that they form a rather deep rounded ventral sinus. The internal mold, but not the exterior of the test, bears transverse constrictions, which form a rather deep ventral sinus. The shape of the sutures of this specimen are shown by text figure 3D.

This species resembles closely *Pseudoparalegoceras russiense* (Tzwetaev) of the Moscovian of Podolsk, U. S. S. R., the genotype of *Pseudoparalegoceras*. We are not able to point out any characters that can be used to differentiate these two species, though a direct comparison of specimens might reveal significant differences. *P. bellilineatum* differs in that its conch is narrower and its test is more prominently ornamented.

*Occurrence.*—The original type specimens all came from below the Kickapoo Falls limestone near the base of the Millsap Lake formation in northern Hood County, Texas. One of the specimens discussed above was collected by John Fitts from the Boggy formation east of Ada, Oklahoma. The other was collected by I. A. Keyte in 1928 from the Magdalena formation near Rowe, San Miguel County, New Mexico, "on the Pecos River, 1.4 miles from the highway in sandstone and limestone near the base of a thick sandstone." The available information seems to indicate that at all three of the localities at which this species occurs, the containing beds are of lower Des Moines age. From the Buckhorn asphalt (upper Des Moines) south of Sulphur, Murray County, Oklahoma, we have a moderately well preserved specimen (State Univ. Iowa, 1432) some 100 mm. in diameter, which is closely similar to *P. brazoense* and may be conspecific with it.

*Hypotypes.*—John Britts Owen collection at State University of Iowa, 13993 (pl. 62, fig. 8) and 13992 (pl. 63, figs. 13, 14).

### PSEUDOPARALEGOCERAS BELLILINEATUM Miller and Furnish, n. sp.

Plate 63, figures 11, 12

*Phaneroceras lenticulare* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701, pp. 193–194, pl. 10, fig. 8 [not figs. 1–7, 9].

Among the numerous specimens of *Pseudoparalegoceras* in our collections from the Magdalena formation of the Sierra Diablo, there are a few that have relatively prominent ornamentation and sutures in which the prongs of the ventral lobe are relatively narrow. In the largest of these, which represents a mature portion of a phragmacone of some 65 mm. diameter, the conch is about 28 mm. high and some 26 mm. wide. At full maturity the lateral zones of the conch are rather strongly flattened. The size of the umbilicus appears to be about average for the genus.

The surface of the test is marked by rather prominent growth lines, which form deep rounded ventral and lateral sinuses. Also, on the ventral zones of the conch there are longitudinal lirae which, however, are not as prominent as the growth lines. None of the specimens on which we are basing this species is marked by transverse constrictions.

The shape of the sutures is represented by text figure 3C. It should be noted that the subdivisions of the ventral lobe are relatively narrow for this genus and that, as in the genotype, the umbilical lobes center just outside the umbilical shoulders.

*Remarks.*—Presumably most of the representatives of *Pseudoparalegoceras* which occur in the Magdalena of the Sierra Diablo are referable to *P. lenticulare* (Plummer and Scott) and *P. compressum* (Hyatt). Since immature representatives of these species probably can not be distinguished from each other or from *P. bellilineatum*, we are not referring any of the small specimens in our collections to the species just described. At least one of the specimens illustrated by Plummer and

Scott (1937, pl. 10, fig. 8) as *Phaneroceras lenticulare* seems to be referable to this species.

*Occurrence.*—Smithwick horizon in the Magdalena formation, about one-fourth mile north of the outer Marble Canyon intrusion in the Sierra Diablo of Culberson County, Texas. The figured specimen was collected by John Emerly Adams.

*Syntypes.*—State University of Iowa, 1420 (figured specimen) and 1421 (unfigured specimens).

### Genus DUNBARITES
Miller and Furnish, n. gen.

Genotype: *Dunbarites rectilateralis* (Miller)

Conch discoidal and whorls flattened laterally and ventrally. Umbilicus moderately large. Test essentially smooth but bears transverse constrictions, which are deepened laterally. Sutures form a total of 10 lobes, the ventral one of which is prominently subdivided.

*Dunbarites* bears some resemblance to *Paralegoceras* in the form of its sutures. Apparently, however, this is only superficial, for *Dunbarites* seems to have evolved from *Eoasianites* late in the Pennsylvanian long after *Paralegoceras* had become extinct. *Paralegoceras* attains a much greater size, and the form and ornamentation of its conch are entirely different.

*Dunbarites* is probably more closely related to *Emilites* than to any other genus, and the two occur at the same general horizon and in the same general area. However in *Emilites* the conch is globular and the umbilicus is small. Ružencev has referred *Emilites* to the Adrianitidae, and it and *Dunbarites* may have given rise to that Permian family.

The type species, *D. rectilateralis*, which is the only known representative of the genus, has been found at only a single locality in the Gaptank formation of the Glass Mountain region in west Texas.

### DUNBARITES RECTILATERALIS (Miller)
Plate 63, figures 1–5

*Paralegoceras rectilaterale* MILLER, *1930*, Jour. Paleontology, vol. 4, pp. 402–403, pl. 38, figs. 12–14; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 22, 34, 198, 200; KING, *1938*, U. S. Geol. Survey, Prof. Paper 187, p. 80; MILLER and FURNISH, *1940*, Geol. Soc. America, Spec. Paper 26, p. 103.

*Plummerites? rectilaterale* MILLER and FURNISH, *1940*, Geol. Soc. America, Spec. Paper 26, p. 13.

Both of the syntypes of this species represent the phragmacone and the adapical portion of the living chamber. In each, the phragmacone attains a maximum diameter of about 9 mm. The fact that both specimens are of essentially the same size suggests that they represent fully mature individuals. No forms that are at all similar were found in the abundant associated fauna.

Transverse constrictions on these specimens are more prominent on the internal mold than on the exterior of the test. One of the specimens bears three of these constrictions in its outer volution, and both of them appear to have a total of five in their outer two volutions. The constrictions form a flattened salient as they cross the ventral side of the conch, and on the lateral sides of the conch they slope apicad from the venter. Near the center of the lateral zones of the conch the constrictions are deepened into rounded pit-like depressions. Comparable lateral depressions occur in some adolescent representatives of *Popanoceras* but are not known to occur in other genera of Paleozoic ammonoids and presumably have no phylogenetic significance.

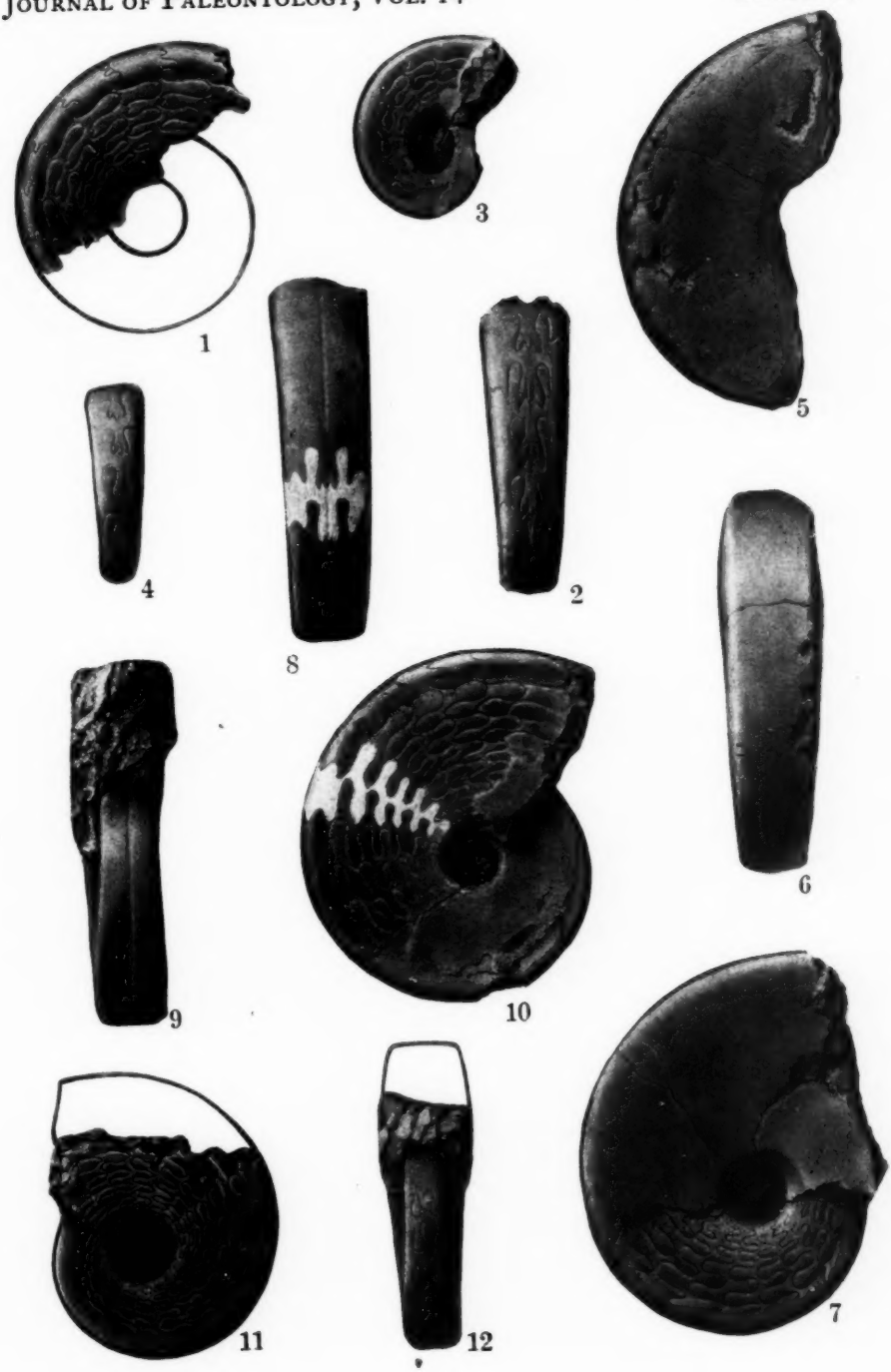
As shown in text figure 4A, each suture forms a total of 10 lobes. The ventral lobe is prominently subdivided. The first lateral lobe, which centers on the ventrolateral shoulder of the conch, is relatively large and is narrowly rounded. The second lateral lobe, which is located outside the umbilical shoulder, is rather shallow and is subangu-

### EXPLANATION OF PLATE 64

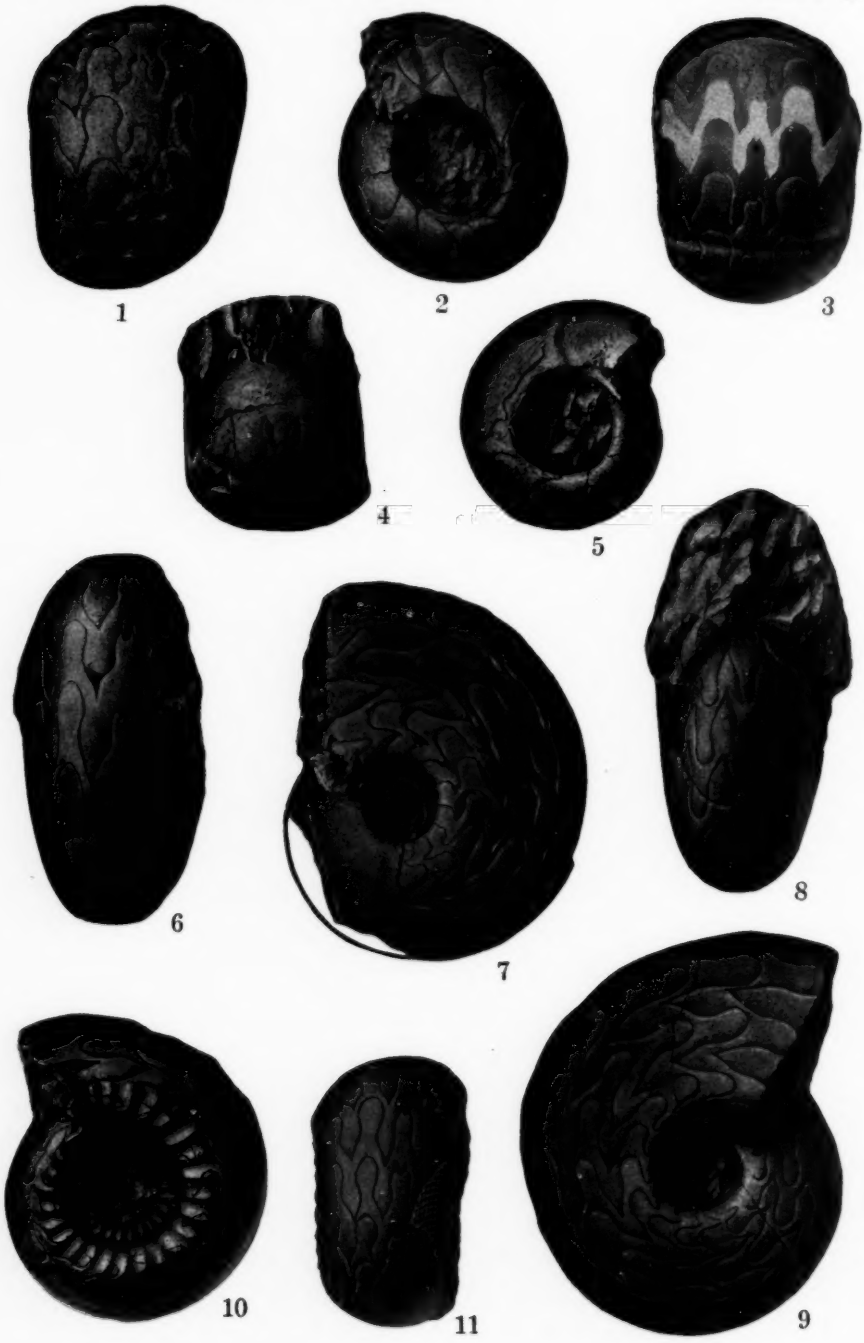
FIGS. *1–7—Prouddenites primus kleihegei*, n. var. *1–4*, Two paratypes from the Nelagoney formation near Wild Horse, Oklahoma, both ×2; *5, 6*, A paratype from the Iola limestone at Kansas City, Missouri, ×1; *7*, The holotype from the same horizon and locality as the last, ×1½. (p. 537)

*8–10—Prouddenites primus primus* Miller. A specimen from the Winterset limestone at Kansas City, Missouri, ×1½. (p. 535)

*11–12—Prouddenites primus clinei*, n. var. The holotype from the Nellie Bly formation west of Sand Springs, Oklahoma, ×1½. (p. 536)




Miller and Furnish, Carboniferous Ammonoids




Miller and Furnish, Carboniferous Ammonoids

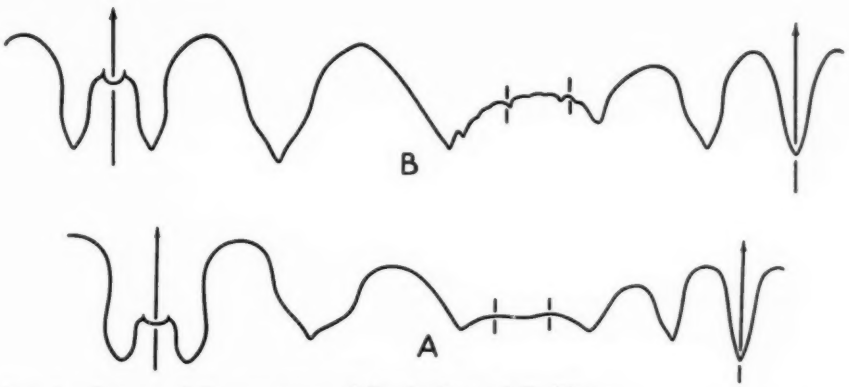



FIG. 4.—Sutures of the genotypes of *Dunbarites* and *Emilites*.
(A) *Dunbarites rectilateralis* (Miller) at a diameter of about 10 mm., ×10; based on one of the syntypes (pl. 63, figs. 1, 2) from the Gaptank formation south of Lenox, Brewster County, Texas.
(B) *Emilites incertus* (Böse) at a diameter of about 10½mm., ×6; based on a topotype from the upper Gaptank formation at Wolf Camp in the Glass Mountains, Brewster County, Texas (Yale Peabody Museum, 16785).

lar. The low broad saddle that extends across the umbilical wall is flattened and slightly depressed. The internal sutures consist of a narrow dorsal lobe and two pairs of smaller lobes.

*Occurrence.*—Upper part of Gaptank formation (zone of *Prouddenites*) about 4.5 miles S. 15° E. of Lenox, Brewster County, Texas.

*Syntypes.*—Yale Peabody Museum, 12934.

### VI. A PROUDDENITES FAUNA FROM KANSAS CITY

For some years Mr. J. B. Kleihege has been collecting fossils from phosphatic nodules in the Muncie Creek shale member of the Iola formation at Kansas City, Missouri. Most of them came from the Main Street cut near the Union Station south to about Twenty-seventh Street. During this work he has obtained representatives of several biologic groups, including fishes, arthropods, and a few cephalopods. The ammonoids, which he loaned to us for study, are not particularly varied, but they are well-preserved, characteristic forms referable to the following species:

*Prouddenites primus kleihegei*, n. var.
*Schistoceras hildrethi* (Morton)
*Schistoceras missouriense* (Miller and Faber)
*Eoasianites* sp.

Furthermore, Mr. Kleihege has found *Prouddenites primus primus* in the Winterset limestone at Kansas City, and the type specimens of *Schistoceras missouriense* and *Eoasianites kansasensis* came from the same area, *Schistoceras missouriense* is also represented in the John Britts Owen collection from near Kansas City (pl. 65, figs. 8, 9).

Typical *Prouddenites* appears to be characteristic of the middle and upper portions of the Missouri series and lower part of the Virgil series, and this horizon can, therefore, be referred to as the zone of *Prouddenites*.

---

EXPLANATION OF PLATE 65

FIGS. *1, 2—Eoasianites merriami*, n. sp. The holotype from the Upper Mills Ranch inlier of Crook County, Oregon, ×1. (p. 542)
*3–5—Eoasianites* sp. Two specimens from the Muncie Creek shale member of the Iola formation at Kansas City, Missouri—*3* is ×1½; *4, 5* are ×1. (p. 541)
*6–9—Schistoceras missouriense* (Miller and Faber). *6, 7*, A specimen from the Muncie Creek shale, ×1½; *8, 9*, Another from the Winterset limestone, ×1—both from the vicinity of Kansas City, Missouri. (p. 540)
*10–11—Schistoceras hildrethi* (Morton). A specimen from the Muncie Creek shale at Kansas City, Missouri, ×1½. (p. 539)

The ammonoid fauna of this zone is known best from the Nellie Bly (Cherryvale) and the Nelagoney formations of northeastern Oklahoma, which have yielded the following species:

*Prouddenites primus clinei* Miller and Furnish
*Boesites texanus* (Böse)
*Imitoceras grahamense* (Plummer and Scott)?
*Eothalassoceras inexpectans* (Miller and Owen)
*Eudissoceras pingue* (Miller and Cline)
*Goniloboceras welleri* Smith?
*Eupleuroceras bellulum* Miller and Cline
*Eupleuroceras?* n. sp.
*Eoasianites millsi* (Miller and Cline)
*Schistoceras hildrethi* (Morton)
*Neoshumardites* n. sp.
*Parashumardites senex* (Miller and Cline)
*Peritrochia ganti* (Smith)

In the general vicinity of Kansas City, *Eoasianites kansasensis*, *Goniloboceras goniolobum?*, *Schistoceras hildrethi*, and *S. missouriense* occur in the Westerville limestone; *Goniloboceras goniolobum?* in the Raytown limestone; and *Stenopronorites kansasensis* and *Goniloboceras goniolobum?* in the Argentine limestone. Also, the Francis formation of the Arbuckle Mountain region in Oklahoma has yielded *Neodimorphoceras oklahomae?* and *Eosianites?* sp., and the overlying Belle City limestone carries *Schistoceras missouriense.*

In north-central Texas the *Prouddenites* fauna occurs in the Graford limestone of the lower Canyon, and the following ammonoid species are known from that formation:

*Prouddenites primus primus* Miller
*Schistoceras hildrethi* (Morton)
*Eoasianites* sp.
*Goniloboceras* sp.
*Parashumardites fornicatus* (Plummer and Scott)

A related fauna containing *Prouddenites*, *Schistoceras*, *Eoasianites*, etc. is known from the upper part of the Gaptank formation of west Texas, but *Uddenites* occurs in this fauna, and therefore it is probably somewhat younger. Faunas of about the same age have been found in Soviet Russia, but relatively little is known in regard to them.

Acknowledgment is hereby made to Mr. J. B. Kleihege of Kansas City who collected the fossils described below, to Mr. Howard Webster of Iowa City who prepared the illustrations that accompany this report, and particularly to Mr. Frederick O. Thompson of Des Moines who made our work financially possible.

### Genus PROUDDENITES Miller, 1930

Genotype: *Prouddenites primus* Miller

Conch discoidal and attains a maximum diameter of at least 65 mm. Living chamber about two-thirds volution in length. Whorls flattened laterally and ventrally and lateral zones are nearly parallel. Umbilicus moderately small and umbilical shoulders fairly abrupt. Growth lines form slight lateral sinuses and then curve orad to form a broad ventral salient which is flattened on the ventral side of the conch. Sutures consist of a deep trifid ventral lobe, a broad prominently subdivided first lateral lobe, a narrow spatulate second lateral lobe, and several auxiliary lobes. The internal sutures consist of a bifid dorsal lobe and several smaller undivided lobes.

The first lateral lobe is perhaps the most distinctive part of the suture in the Pronoritidae and the Medlicottidae, which are more or less connected by *Prouddenites* and *Uddenites*. In the Pronoritinae, the first lateral lobe is relatively stable and is symmetrically bifid. In the Uddenitinae, which we regard as a subfamily of the Pronoritidae, the first lateral lobe is asymmetrical and is quite variable; the ventral portion of this lobe is greatly modified, whereas the dorsal portion remains relatively simple.

In *Prouddenites*, the first lateral lobe is typically trifid. Each of its three divisions may, however, be secondarily subdivided, though the dorsal one is undivided in almost all cases. In some 50 per cent of the numerous specimens we have studied, the secondary subdivisions of the first lateral lobe are not equally developed on the two sides of the conch. As might be expected, neither the right nor the left side of the conch is consistently more advanced than the other.

The oldest and most primitive species of this genus is represented by a few well-preserved but fragmentary specimens in our collections from about 3 miles south of Sulphur, Murray County, Oklahoma, in the Buckhorn asphalt, which contains *Weller-*

*ites, Gonioglyphioceras?, Goniolobоceras, Eoasianites, Pseudoparalegoceras, Paralegoceras?*, and *Bisatoceras*, and is of about the same age as the Wewoka formation. These fragmentary specimens do not merit illustrations or serve as a satisfactory basis for the erection of a species. However, they show clearly that when the conch attained a diameter of 15–20 mm. it was flattened laterally and ventrally and that the first lateral saddle of its sutures was incipiently trifid; that is, this lobe was asymmetrically bifid, and an additional subdivision was starting to develop on the ventral prong. This form is such a primitive representative of *Prouddenites* that it resembles *Pronorites* in certain respects, but the shape of its conch and the ventral portions of its sutures indicate an affinity with *Prouddenites*.

Ružencev has collected another primitive representative of *Prouddenites* from the Orenburgian (Upper Pennsylvanian) of the southern Ural region. Its conch is discoidal and is somewhat flattened ventrally. Ružencev kindly sent us, in advance of publication, a diagrammatic representation of one of its sutures, which we are reproducing as text figure 1A. This suture is not typical of *Prouddenites*, but the first lateral lobe is asymmetrically bifid with each point secondarily subdivided. The general shape of the conch and the fact that the ventral prong of the first lateral lobe is larger than the dorsal prong, indicate that this form is more closely related to *Prouddenites* than to typical pronoritids.

Typical *Prouddenites* was originally described from the Gaptank formation of west Texas, and it has since been found in the Graford formation of north-central Texas, the Nellie Bly and Nelagoney formations of northeastern Oklahoma, and the Winterset and Iola limestones of west-central Missouri. At all of these numerous horizons and localities the specimens are so similar that we believe they should be regarded as representing only one species, though we are recognizing varietal differences. With the exception of the primitive form found near Sulphur in south-central Oklahoma, all of the American representatives of *Prouddenites* occur in a limited section embracing the Missouri series and basal part of the Virgil series.

### PROUDDENITES PRIMUS Miller

Plate 64, figures 1–12

*Prouddenites primus* MILLER, *1930*, Jour. Paleontology, vol. 4, pp. 397–400, pl. 38, figs. 3–10; MILLER and CLINE, *1934*, Jour. Paleontology, vol. 8, p. 177, pl. 28, figs. 1–3; SELLARDS, *1932*, Texas Univ. Bull. 3232, p. 112; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 34, 61, 62; MILLER and FURNISH, *1940*, Geol. Soc. America, Spec. Paper 26, pp. 12, 35, 38.

*Prouddenites bösei* PLUMMER and SCOTT, *1937* [part], Texas Univ. Bull. 3701, pp. 17, 22, 34, 61, 62–63, 64, 387, pl. 2, figs. 9, 10. [Not *Parapronorites boesei* Smith, 1929.]

*Prouddenites grafordensis* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 63–64, pl. 2, figs. 11–15.

*Pronorites grafordensis* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 380.

Conch attains a maximum diameter of at least 65 mm. and a corresponding height of conch of about 36 mm. and width of conch of about 17 mm. (estimated). Where the figured type specimen is about 32 mm. in diameter, its conch is about 17 mm. high and about 10 mm. wide, and its umbilicus is about 6 mm. in diameter. The specimen represented by figures 8–10 on plate 64 is about 33 mm. in diameter, its conch attains a height of about 17 mm. and a width of about 10 mm. (estimated), and its umbilicus is about 6½ mm. in diameter. We have one large specimen about 65 mm. in diameter that appears to be almost complete adorally, and it shows that the living chamber is about two-thirds of a volution in length. As in many pronoritids, on the internal mold there is a stria along the venter of typical forms at maturity.

The large collections now available show that there is considerable variation within this species, and some of the variants seem to be stable enough to merit varietal recognition. The specimen represented by figures 11, 12 on plate 64, which is the only mature representative of the genus known from the Nellie Bly formation, is distinctly narrower and less strongly flattened ventrally than the type specimens, its umbilicus is relatively larger, and there is no stria along its venter. Where the diameter of this specimen measures about 22 mm., the conch is about 10 mm. high and about 6 mm. wide and the umbilicus is about 6 mm. in diameter—the conch of a typical topotype of the species (text fig. 5D) at the same diameter is about 11 mm. high and about 7¼ mm.

wide. The sutures of the Nellie Bly specimen are in general similar to those of topotypes but as shown by text figures 5B and 5D, the lobes of the specimen under consideration are relatively narrow, which is a result of the fact that its whorls are relatively low and narrow. For this Nellie Bly specimen, we propose the name *P. primus clinei*.

The specimen represented by figure 7 on plate 64 is the holotype of another new va-

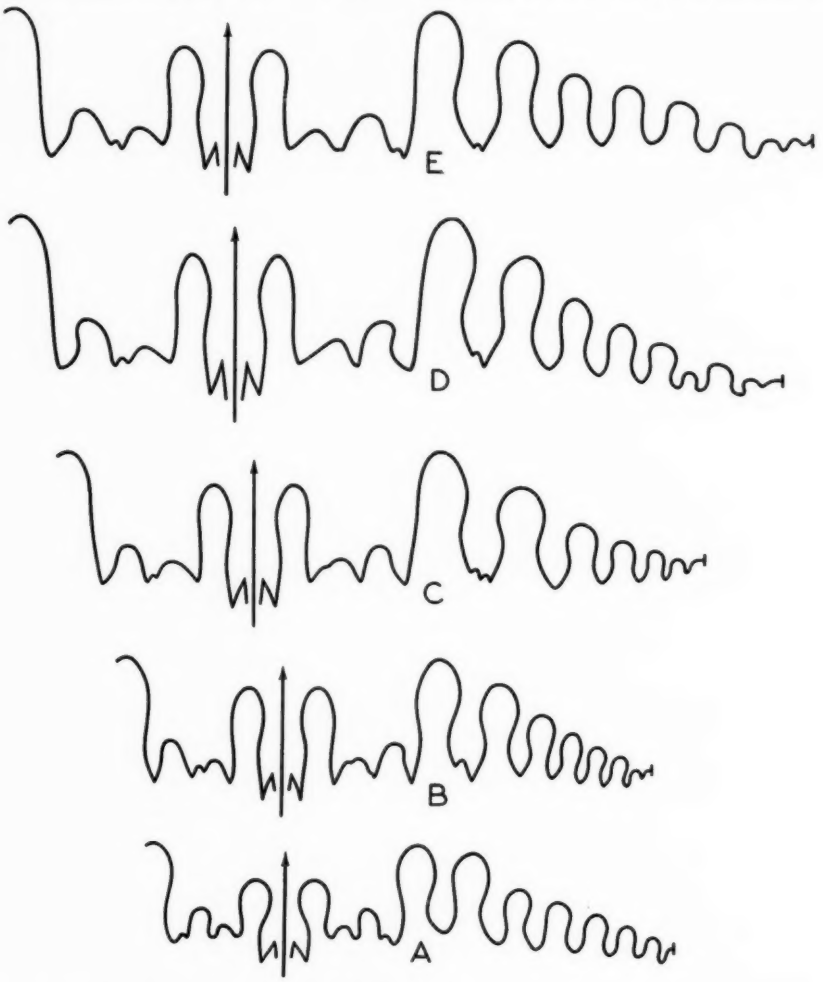



FIG. 5.—Mature external sutures of *Prouddenites*.

(A) *Prouddenites?* sp., ×4½; based on a specimen from the Orenburgian of the southern Ural region. Drawn by Ruženčev.

(B) *Prouddenites primus clinei*, n. var., at a diameter of about 22 mm., ×4; based on the holotype from the Nellie Bly formation west of San Springs, Oklahoma.

(C) *Prouddenites primus kleihegei*, n. var., at a diameter of about 24 mm., ×5; based on the holotype from the Iola formation at Kansas City, Missouri.

(D) *Prouddenites primus primus* Miller at a diameter of about 26 mm., ×4½; based on a well-preserved topotype (State University of Iowa, 2039) from the Gaptank formation of the Glass Mountain region, west Texas.

(E) *Prouddenites primus primus* Miller at a diameter of about 33 mm., ×4; based on the specimen represented by figures 8–10 on plate 64, from the Winterset limestone at Kansas City, Missouri.

riety, *P. primus kleihegei*. This variety differs from both the typical one and from *P. primus clinei* in that its sutures form fewer lobes. Also, its conch is narrower and its umbilicus is larger than are those of *P. primus primus*, and there is no stria along its venter. Furthermore, in the sutures of the holotype under consideration, the second lateral lobe is distinctly trifid, and in a specimen (pl. 64, figs. 1, 2) from the Nelagoney formation of Oklahoma which we are referring to this variety, the second lateral lobe is similarly trifid and the third lateral lobe is incipiently divided. Although these characters are probably not of fundamental importance, it may be worthy of note that in none of the numerous representatives of the typical variety that we have examined, or in *P. primus clinei*, are these features developed.

The sixth and the seventh lateral lobes of the specimen represented by text figure 5D developed by the sixth lateral lobe becoming bifid. This development is confined to one side of the specimen, and we have not observed a similar development in any other pronoritid or medlicottid. Presumably, no particular significance is to be attached to it, but it is reminiscent of the development of the lobes in the Popanoceratidae.

*Occurrence.*—The typical variety of this species is abundant in the Gaptank formation at one locality about 4½ miles S. 15° E. of Lenox, Brewster County, Texas, and we are referring to it a single specimen from the Winterset limestone at Kansas City, Missouri. A few small immature specimens which appear to be referable to this variety have been found in the Graford shale at Bridgeport, Wise County, Texas. The name *P. grafordensis* was coined for these by Plummer and Scott, but we have a topotype of some 10 mm. diameter, and it seems to be identical with equal-sized representatives of *P. primus primus*. The holotype of *P. primus clinei* was found in the Nellie Bly (Cherryvale) formation about 6½ miles west of Sand Springs, Tulsa County, Oklahoma, and the same locality has yielded several immature specimens. The holotype and one paratype of *P. primus kleihegei* came from the Muncie Creek shale member of the Iola limestone at Kansas City, Missouri; also, we are referring to this variety four specimens from the Wildhorse member of the Nelagoney formation at Wild Horse, about 12 miles west of Skiatook, Osage County, Oklahoma. (We have about a dozen small specimens from the same locality.)

*Types.*—The syntypes of this species are at the Yale Peabody Museum, where they are numbered 12932 and 12942. The specimens represented by figures 5–10 on plate 1 are in the private collection of J. B. Kleihege of Kansas City, Missouri. All of the other specimens mentioned above are at the State University of Iowa, where they are numbered 634 (holotype of *P. primus clinei*) 1422 (pl. 64, figs. 1, 2), 1423 (pl. 64, figs. 3, 4), 1424–1430, 2039 (text fig. 5D), 13989 and 13990 (John Britts Owen collection at State Univ. Iowa).

### Genus SCHISTOCERAS Hyatt, 1884

Genotype: *Goniatites missouriensis* Miller and Faber

Conch subglobular to subdiscoidal and moderately large. Whorls somewhat depressed, rounded ventrally, slightly flattened laterally, and impressed dorsally. Living chamber appears to be about one volution in length. Diameter of umbilicus, which becomes relatively smaller during late ontogenetic development, varies from about one-fourth to about one-half diameter of specimen. During adolescence umbilical shoulders are nodose, but nodes are lost before or during early maturity. Surface of test at maturity is marked by transverse growth lines and typically by longitudinal lirae. Growth lines form a deep rounded ventral sinus, prominent rounded ventrolateral salients, and shallow lateral sinuses. Sutures consist of a large very prominently bifid ventral lobe, four pairs of pointed-spatulate external lateral lobes, a narrow pointed dorsal lobe, two pairs of similar internal lateral lobes—altogether each mature suture consists of 14 lobes.

During rather early ontogenetic development, the sutures pass through a gastrioceran stage in which each consists of eight lobes. Then the umbilical lobes become lateral in position and a paralegoceran stage is achieved as on each side of the conch a lobe is developed in the umbilical zone. This lobe becomes trifid and evolves into three lobes, the dorsal one of which is internal in

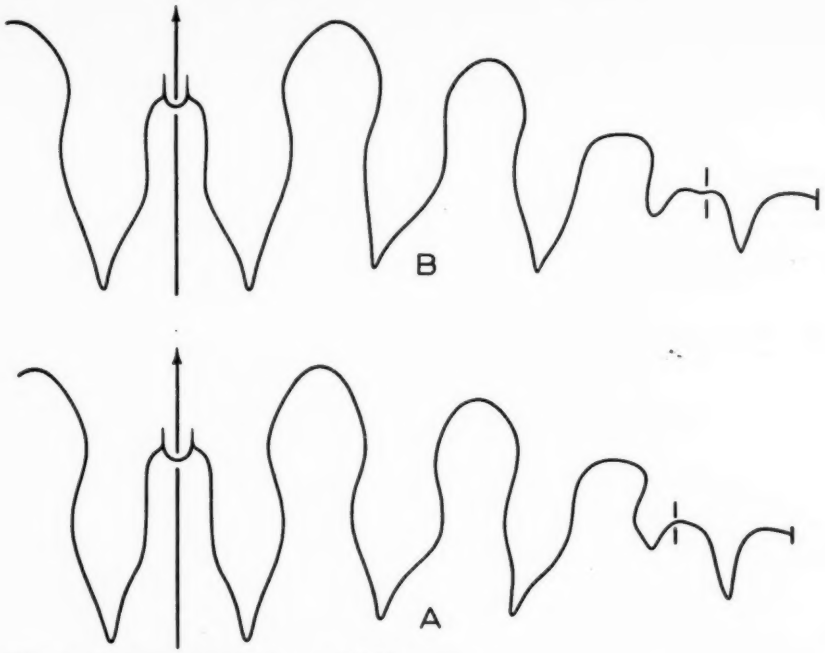



FIG. 6.—Mature external sutures of *Schistoceras*.
(A) *S. hildrethi* (Morton) at a diameter of about 25 mm., ×6; based on the specimen represented by figures 10, 11 on plate 65.
(B) *S. missouriense* (Miller and Faber) at a diameter of about 35 mm., ×4; based on the specimen represented by figures 6, 7 on plate 65.

position. In some cases the ventral one of these three becomes bifid, but this character is variable and apparently is to be accorded little taxonomic value. The sutures of *Schistoceras* are never comparable to those of *Metalegoceras;* in that genus the umbilical lobe of the gastrioceran stage becomes trifid and evolves into three lobes. In *Texoceras* and other adrianitids, both external and internal lateral lobes are added consecutively in the umbilical zone rather than developed from a trifid umbilical lobe. The *Paralegoceras-Schistoceras* stock is one of the most important in the Pennsylvanian, but apparently it became extinct at or near the end of that period.

In spite of the fact that several paleontologists have emphasized that all of the known representatives of *Schistoceras* are very similar, they have been divided into 11 species and three genera. We have assembled a large collection from various horizons and localities, and a direct comparison of specimens has convinced us that only two forms are distinct enough to be recognized as species. One of these, which should be called *S. hildrethi* (Morton), is characterized by a large umbilicus, nodose umbilical shoulders during early maturity, and relatively prominent reticulate ornamentation. In the second species, *S. missouriense* (Miller and Faber), the umbilicus is relatively small, during early maturity the umbilical shoulders are smooth, and the ornamentation of the test is relatively fine and inconspicuous. All of these features are of course more or less gradational, and forms are known that are intermediate between the two species. Furthermore, the two occur at several localities in direct association.

Smith proposed the name *S. hyatti* for the specimen on which the genus was based. However, we are suppressing that specific name as a synonym of *S. missouriense*, which then becomes the genotype. In our opinion *Paraschistoceras* and *Metaschistoceras* are synonyms of *Schistoceras*.

The genus *Schistoceras* is now known from

the lower Conemaugh of eastern Ohio and western Pennsylvania and the McLeansboro of central Illinois. In the Missouri-Kansas-Oklahoma Mid-Continent region it occurs at numerous horizons and localities ranging in age from the basal Missouri Coffeyville formation of Oklahoma to the Douglas group of the Virgil series in Kansas. In north central Texas, this genus is known from the upper Strawn, the Canyon, and possibly the Wichita; and in west Texas, it ranges throughout most of the Gaptank. The specimen from central Asia, which in 1931 Miller tentatively placed in this genus, almost certainly does not belong here.

SCHISTOCERAS HILDRETHI (Morton)
Plate 65, figures 10, 11

*Ammonites hildrethi* MORTON, *1836*, Am. Jour. Sci., vol. 29, pp. 40, 149, pl. 1, fig. 24 [probably not p. 137, pl. 28, figs. 48, 50, 53, 54].
*Goniatites hildrethi* MILLER, *1889*, North American geology and palaeontology . . . , p. 439.
*Agathiceras hildrethi* HAUG, *1898*, Soc. géol. France, Mém., Paléont., no. 18, pp. 33, 105–107, pl. 1, figs. 40a–c.
*Schistoceras hildrethi* SMITH, *1903*, U. S. Geol. Survey, Mon. 42, pp. 107–108, pl. 3, figs. 1, 2.
*Schistoceras reticulatum* MILLER, *1930*, Jour. Paleontology, vol. 4, pp. 403–406, pl. 39, figs. 6–9.
*Schistoceras unicum* MILLER and OWEN, *1937*, Jour. Paleontology, vol. 11, pp. 420–422, pl. 52, figs. 16, 17.
*Paraschistoceras hildrethi* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 17, 18, 22, 30, 33, 207, 240, 244, 247, 248, 250–251, 253, 255, 257, 379, 380, 387, 389, 390, pl. 14, figs. 1–14.
*Paraschistoceras reticulatum* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 16, 17, 21, 22, 34, 246, 247, 253–255, 380, 382, 387, 388, 394, 399, pl. 14, figs. 15–18.
*Paraschistoceras strawnense* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 16, 17, 247, 248–249, 387, pl. 14, figs. 22, 23.
*Paraschistoceras costiferum* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 17, 252–253, 255, pl. 14, figs. 19–21.

In 1836, Morton figured several specimens on which he based this species, but from his illustrations we are able to recognize the generic affinities of only one of them (Morton's pl. 1, fig. 24). This one may well be the same individual that Haug later found in a collection which Hildreth, who collected the types, had sent to France. Because of the measurements given by Morton, Haug concluded that he was probably not studying one of the original type specimens, but we find that Morton's measurements elsewhere in the same paper are inconsistent. Furthermore, it is probably significant that Morton's illustrations are of almost precisely the same size as Haug's specimen, that in each case the specimens are stated to be silicified internal molds, and that insofar as it is possible to make comparisons the figures appear to be identical. Since Morton's illustrations are quite inadequate and his specimens are lost, whereas Haug's figures are quite satisfactory, we propose to regard the specimen studied by Haug as the type of the species.

It should be made clear that the type specimens of the first four "species" of this genus that were named are internal molds. Therefore, it is difficult to evaluate species established later and based on differences in shell ornamentation. Ordinarily topotypes might be expected to elucidate the surface ornamentation of the first-named species, but the large collections available to us show that widely different types occur in direct association. Certain of the specific names that have been proposed could perhaps be recognized by relegating them to the rank of varieties, but the differences on which they rest are so inconsequential that little is to be gained by such a procedure.

The shape of the conch and the nature of the ornamentation and the sutures vary throughout ontogenetic development. During adolescence the umbilicus is relatively large, the umbilical shoulders are nodose, and the surface ornamentation of the test is relatively prominent. These ontogenetic variations, together with differences in preservation, are sufficient to explain most of the characters on which species have been based. There is, to be sure, more or less gradation between *S. hildrethi* and *S. missouriense*, but we believe that the extremes within the group are worthy of specific recognition.

*Occurrence.*—The only one of the original type specimens of which we can recognize the generic affinities came from the Cambridge limestone (lower Conemaugh) near Cambridge, Guernsey County, Ohio. This may be the same specimen that was figured by Haug in 1898. We have a congeneric specimen from the same horizon and locality,

but it is clearly not conspecific, being referable to *S. missouriense*. Specimens that we regard as belonging in *S. hildrethi* are also known from the following horizons and localities: the Brush Creek limestone (lower Conemaugh) near Pittsburgh, Pennsylvania; the McLeansboro of Sangamon County, Illinois; the Muncie Creek member of the Iola formation (Kansas City group) at Kansas City, Missouri; the Iatan limestone of the Pedee group and the Stranger formation of the Douglas group in Douglas County, Kansas; the Seminole and Nellie Bly formations of Tulsa County, Oklahoma; the Nelagoney formation of Osage County, Oklahoma; the upper Strawn of Palo Pinto County, north central Texas; the Graford formation of Palo Pinto and Wise counties, north central Texas; the Graham formation of Brown, Jack, McCulloch, Stephens, and Young counties, north-central Texas; and the upper Gaptank formation of Brewster County, Texas.

*Hypotypes.*—The figured specimen (pl. 65, figs. 10, 11) is in the private collection of J. B. Kleihege of Kansas City, Missouri. Other specimens available to us are in the Yale Peabody Museum (Texas), the Carnegie Museum at Pittsburgh (Pennsylvania), the University of Kansas (Kansas), and the State University of Iowa where the John Britts Owen collection is now deposited (Oklahoma and Texas).

### SCHISTOCERAS MISSOURIENSE
(Miller and Faber)
Plate 65, figures 6–9

*Goniatites missouriensis* MILLER and FABER, *1892*, Cincinnati Soc. Nat. History, Jour., vol. 14, pp. 164–165, pl. 6, fig. 1.
*Schistoceras* sp. HYATT, *1884*, Boston Soc. Nat. History, Proc., vol. 22, p. 336.
*Goniatites fultonensis* MILLER and GURLEY, *1896*, Ill. State Mus. Nat. Hist., Bull. 11, pp. 39–40, pl. 4, figs. 15–17.
*Paralegoceras iowense* SMITH, *1896* [part], Am. Phil. Soc., Proc., vol. 35, pp. 263, 265.
*Agathiceras fultonensis* HAUG, *1898*, Soc. géol. France, Mém., Paléont., no. 18, p. 33.
*Schistoceras fultonense* SMITH, *1903*, U. S. Geol. Survey, Mon. 42, pp. 106–107, pl. 16, figs. 15–17; MORGAN, *1924* [Oklahoma] Bur. Geol., Bull. 2, p. 124, pl. 53, figs. 8, 8a.
*Schistoceras hyatti* SMITH, *1903*, U. S. Geol. Survey, Mon. 42, pp. 108–111, pl. 20, figs. 1–8; pl. 21, figs. 10a–13; PLUMMER and MOORE, *1921*, Texas Univ. Bull. 2132, pp. 145, 146, 149, pl. 22, fig. 10; SELLARDS, *1932*, Texas Univ. Bull. 3232, p. 114.
*Schistoceras missouriense* SMITH, *1903*, U. S. Geol. Survey, Mon. 42, p. 111, pl. 8, fig. 1; SAYRE, *1930*, Kansas Univ. Sci. Bull., vol. 19, pt. 2, p. 158, pl. 21, figs. 4, 4a; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 17, 18, 30, 33, 201, 202–204, 206, 388, 399, pl. 19, figs. 1–15; pl. 20, fig. 11.
*Schistoceras smithi* BÖSE, *1919*, Texas Univ. Bull. 1762, pp. 93–95, pl. 3, figs. 9–16; MILLER, *1930*, Jour. Paleontology, vol. 4, pp. 406–407, pl. 39, figs. 14–16; PLUMMER and SCOTT, Texas Univ. Bull. 3701, pp. 17, 22, 32, 34, 201, 205–206, 303, 387, 388, pl. 18, figs. 1–7; pl. 41, figs. 6–8.
*Schistoceras diversecostatum* BÖSE, *1919*, Texas Univ. Bull. 1762, pp. 96–99, pl. 4, figs. 1–36; SMITH, *1929*, Am. Jour. Sci., 5th ser., vol. 17, pp. 76–77, figs. B1–B13; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 17, 22, 32, 34, 201, 206–207, 251, 255, 389, pl. 20, figs. 1–10.
*Metaschistoceras heilprini* PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 247, 256–257, 380, pl. 41, figs. 1–5.

The holotype of this species represents only one side of the conch; it is a rather well preserved internal mold. Small fragments of the reticulate test adhere to the holotype, and conspecific testiferous specimens are known from the Graham formation of north-central Texas. Moderate-sized specimens have rather inconspicuous shell ornamentation, but during late maturity rather prominent longitudinal lirae are developed. On large specimens these longitudinal markings are distinctly more prominent than the transverse growth lines.

In large specimens of "*Metaschistoceras heilprini*," the third lateral lobe of the sutures is prominently bifid. However, we have a specimen in which this lobe is bifid on only one side of the conch, and, therefore, we are of the opinion that no particular taxonomic value should be accorded this feature.

In general, the characters of this species are slightly more advanced than are those of *S. hildrethi*, but all features are not consistent in this respect. In *S. hildrethi*, the umbilicus is larger and the umbilical nodes and prominent reticulate ornamentation of the test are retained until a much larger size is attained by the conch.

*Occurrence.*—The holotype of this species came from the Kansas City group at Kansas City, Missouri. Specimens which we regard as conspecific are now known from the

following horizons and localities: the Winterset, Westerville, and Iola (Muncie Creek member) formations at or near Kansas City, Missouri; the McLeansboro? of Fulton County, Illinois; the LaSalle limestone (McLeansboro) of LaSalle County, Illinois; the Cambridge limestone (lower Conemaugh) of Guernsey County, Ohio; the Brush Creek limestone (lower Conemaugh) near Pittsburgh, Pennsylvania; the Belle City limestone of Seminole County, Oklahoma; the Graford formation of Wise County, north central Texas; the Graham formation of Brown, Jack, Stephens, and Young counties, north-central Texas; the Gaptank formation of Brewster and Pecos counties, west Texas; and possibly the Belle Plains formation (Wichita) of Callahan County, north-central Texas.

*Types.*—The collections of the Walker Museum at the University of Chicago contain the holotype of this species (no. 8756) and the holotype of *Goniatites fultonensis* (no. 6215), which we regard as conspecific. One of the specimens figured in the present report (pl. 65, figs. 6, 7) is in the private collection of J. B. Kleihege of Kansas City, Missouri; the other (pl. 65, figs. 8, 9) is in the John Britts Owen collection at the State University of Iowa (no. 13988). Other specimens available to us are in the Yale Peabody Museum (north central and west Texas), the Carnegie Museum at Pittsburgh (Pennsylvania), the State University of Iowa (Ohio, and north central and west Texas), and Columbia University (Oklahoma—the specimen represented by figs. 8, 8a on Morgan's pl. 53 of 1924 and an unfigured specimen are numbered 18484).

### EOASIANITES sp.
### Plate 65, figures 3–5

The available collections from the Muncie Creek shale contain four specimens that are referable to *Eoasianites*. All are probably conspecific, though the smallest one (pl. 65, fig. 3) has sutures that are distinctly more primitive than are those of the other three.

The whorls are strongly depressed ventrally, and the umbilicus is relatively large. The first lateral lobes and the prongs of the ventral lobe are particularly narrow for this genus. In general physiognomy and in the shape of its sutures this form seems to resemble rather closely *Eoasianites jonesi* of the Coffeyville formation of Oklahoma, *E. excelsus* of the basal Wabaunsee of Kansas, and *E. globulosus* of the Pennsylvanian of Kansas and Illinois. *E.? kansasensis*, the holotype of which came from the Kansas City group at Kansas City, Missouri, is not very similar to the Muncie Creek form. Its sutures (which are not correctly portrayed by Miller and Gurley and by J. P. Smith) resemble those of *E.? illinoisensis* very closely, and these two forms, which may be conspecific, can be said to be intermediate between *Eoasianites* and *Neoshumardites*.

*Occurrence.*—Muncie Creek shale member of Iola formation at Kansas City, Missouri.

*Figured specimens.*—Both of the figured specimens and two unfigured ones are in the private collection of J. B. Kleihege of Kansas City, Missouri.

## VII. A GASTRIOCERATID FROM CENTRAL OREGON

Recently Dr. Charles W. Merriam sent us for study a single well-preserved ammonoid from the Upper Mills Ranch inlier in the upper Crooked River Basin of southeastern Crook County, Oregon. This specimen was found in "float" some time ago by a party working under the direction of Professor E. L. Packard of the University of Oregon. It is the first Late Paleozoic ammonoid to be recorded from this part of the country.

Inasmuch as strata of several ages are present in this inlier and the specimen under consideration is not associated with other fossils, its precise age is uncertain. It belongs in the genus *Eoasianites* which is known to be world-wide in its occurrence and to range from the Upper Mississippian (Chester) up into the Lower Permian (Wolfcamp). The Oregon specimen seems to resemble forms that have been described from the Somohole beds of Timor and the Sakmarian beds of the southern Ural region more closely than any other known species. Both the Somohole and the Sakmarian beds are of Lower Permian, that is, Wolfcamp age. In America, *Eoasianites* is not well known from the Lower Permian, but it is abundant in the Upper Pennsylvanian. Furthermore, some of the Upper Pennsylvanian forms are similar to the Oregon specimen. Therefore,

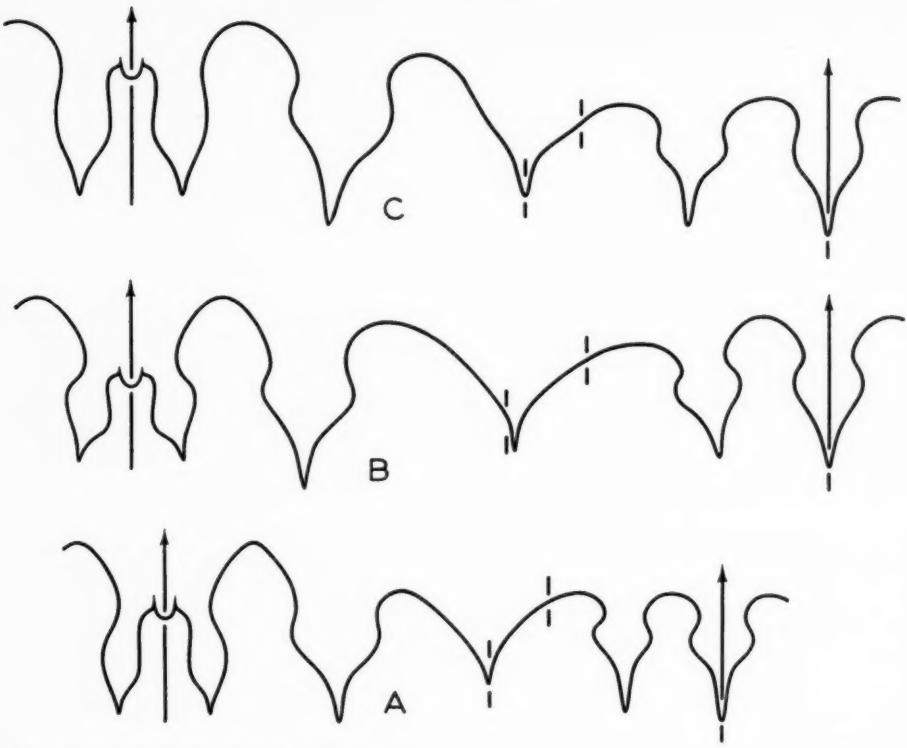



FIG. 7.—Complete sutures of *Eoasianites*.
(A) *E. beluensis* (Haniel) at a diameter of some 30 mm., ×3; based on two specimens from the Somohole beds of Timor. Adapted from Haniel.
(B) *E. merriami*, n. sp., at a diameter of about 35 mm., ×2½; based on the holotype from the Upper Mills Ranch inlier of Crook County, Oregon.
(C) *E. shikhanensis* (Ružencev) at a diameter of some 50 mm., ×2., based on the holotype from the Sakmarian of the Ural region. Adapted from Ružencev.

insofar as we can tell from this one individual, the beds which yielded it are probably of Upper Pennsylvanian or Lower Permian age.

EOASIANITES MERRIAMI
Miller and Furnish, n. sp.
Plate 65, figures 1, 2

Conch is subglobular, and whorls are low and broad. Holotype, only known representative of species, is a silicified internal mold representing the ninth and tenth volutions of the phragmacone. It was somewhat distorted during preservation but is fairly well preserved. Maximum diameter of preserved part of this specimen appears to have been some 35 mm., and maximum height and width of conch about 12½ mm. and 30 mm. respectively. The umbilicus is large, and its diameter is about one-half that of conch. Umbilical shoulders abrupt.

Internal mold marked by prominent transverse constrictions, of which there are about four to the volution. These are essentially straight and are directly transverse. No trace of growth lines or external ornamentation of test is preserved on this specimen.

As shown by text figure 7B, each suture consists of a total of eight lobes, only the ventral one of which is bifid. All of the lobes are pointed and with the exception of the umbilical lobe all are hastate. The first lateral saddle and the first lateral lobe are of about the same size and shape, with the exception that the saddle is rounded, whereas the lobe is pointed.

*Remarks.*—The sutures of this species are closer to those of *E. beluensis* (Haniel) of the Somohole beds of Timor and *E. shikhanensis* (Ružencev) of the Sakmarian of the southern Ural region than to those of any other described species (cf. text figs. 7A–7C). The umbilicus in both of these species appears to be somewhat smaller than in the specimen under consideration, and the whorls appear to be relatively higher and narrower. However, in general physiognomy, the conch is very similar in all three species, and the apparent differences may have been accentuated by distortion during preservation.

In order to avoid any possibility of ambiguity, it should be stated clearly that *Eoasianites* is abundantly represented in the Pennsylvanian as well as in the Lower Permian. Furthermore, forms of the same general type as *E. merriami* are not rare in the Upper Pennsylvanian.

Ružencev designated *Gastrioceras beluense* Haniel as the type of a new genus, *Somoholites*. He stated that it differs from *Eoasianites* in that the lateral lobes of its sutures are more strongly hastate, and its test bears fine longitudinal lirae. In our opinion these differences are not of generic significance, inasmuch as we have several specimens from different horizons and localities that are longitudinally lirate but otherwise are typical of *Eoasianites*. Furthermore, there is complete gradation between the sutures of typical *Eoasianites* and the genotype of *Somoholites*, and we believe that a generic stage should not be recognized until the lateral lobes become incipiently trifid, as in *Neoshumardites*.

*Occurrence.*—Upper Mills Ranch inlier in the upper Crooked River Basin, southeastern Crook County, Oregon.

*Holotype.*—Univ. Oregon, 2202–3.

## REFERENCES


CRONEIS, CAREY, *1930*, Triangular nepionic coiling in Carboniferous ammonoids: *Science*, n. ser., vol. 72, pp. 534–535.

DELÉPINE, G., *1939*, Goniatites nouvelles du Carbonifère des confins algéro-marocains du sud: Soc. Géol. Nord, Ann., tome 64, pp. 28–38, pl. 1.

HANIEL, C. A., *1915*, Die Cephalopoden der Dyas von Timor: *Palaeontologie von Timor*, Lief. 3, Abh. 6, pp. 1–153, pls. 46(1)–56(11).

HAUG, ÉMILE, *1898*, Études sur les goniatites: *Soc. géol. France, Mém., Paléontologie*, no. 18, pp. 1–112, pl. 1.

MENCHIKOFF, NICOLAS, *1930*, Recherches géologiques et morphologiques dans le nord du Sahara occidental: *Rev. Géographie phys. et Géologie dynamique*, vol. 3, fasc. 2, pp. 103–247, pls. 13–20, 1 map.

MILLER, A. K., *1930*, A new ammonoid fauna of Late Paleozoic age from western Texas: *Jour. Paleontology*, vol. 4, pp. 383–412, pls. 38, 39.

——, *1934*, *Pseudoparalegoceras*, a new genus of Carboniferous ammonoids: *Jour. Paleontology*, vol. 8, pp. 18–20, pl. 2.

MILLER, A. K., and CLINE, L. M., *1934*, The cephalopod fauna of the Pennsylvanian Nellie Bly formation of Oklahoma: *Jour. Paleontology*, vol. 8, pp. 171–185, pl. 28.

MILLER, A. K., and FURNISH, W. M., *1940*, Permian ammonoids of the Guadalupe Mountain region and adjacent areas: *Geol. Soc. Am., Spec. Paper* 26, pp. 1–242, pls. 1–44.

MORTON, S. G., *1836*, . . . Notice and description of the organic remains [from the valley of the Ohio] . . . , *Am. Jour. Sci.*, vol. 29, pp. 149–154, pls. 1–36.

PLUMMER, F. B., and SCOTT, GAYLE, *1937*, Upper Paleozoic ammonites in Texas: *Texas Univ. Bull.* 3701, pp. 1–516, pls. 1–41.

RAKUSZ, GYULA, *1932*, Die oberkarbonischen Fossilien von Dobsina (Dobšina) und Nagyvisnyó: *Geol. Hungarica*, ser. pal., fasc. 8, pp. 1–224, pls. 1–9.

READ, C. B., and MERRIAM, C. W., *1940*, A Pennsylvanian flora from central Oregon: *Am. Jour. Sci.*, vol. 238, pp. 107–111.

RUŽENCEV, V. E., *1938*, Ammonoids of the Sakmarian stage and their stratigraphic significance: *Problems of Paleontology* (Moscow), vol. 4, pp. 187–285, pls. 1–7.

SAYRE, A. N., *1930*, The fauna of the Drum limestone of Kansas and western Missouri: *Kansas Univ., Sci. Bull.*, vol. 19, pt. 2, pp. 75–203, pls. 1–21.

SCHINDEWOLF, O. H., *1937*, Zur Stratigraphie und Paläontologie der Wocklumer Schichten (Oberdevon): *Preuss. geol. Landesanstalt Abh.*, N. F., Heft 178, pp. 3–132, pls. 1–4.

SMITH, J. P., *1903*, The Carboniferous ammonoids of America: *U. S. Geol. Survey, Mon.* 42, pp. 1–211, pls. 1–29.

THOMAS, H. D., *1928*, An Upper Carboniferous fauna from the Amotape Mountains, northwestern Peru: *Geol. Mag.*, vol. 65, pp. 146–152, 215–234, 289–301, pls. 5–8, 10–12.


MANUSCRIPT RECEIVED BY THE EDITOR MARCH 24, 1940.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 6, PP. 544–567, PLS. 66–68, NOVEMBER, 1940

# MISSISSIPPIAN INADUNATA—EUPACHYCRINUS AND RELATED FORMS

A. H. SUTTON AND VIRGIL D. WINKLER
University of Illinois, Urbana, Illinois

ABSTRACT—Criteria for classification of the varied *Eupachycrinus*-like crinoids of the Mississippian strata are evaluated and these forms are separated into four genera and one collective group, of which two genera and the collective group are new. Classification is based on three features: number of arms; type of arm structure, uniserial or biserial; and the number, shape, and position of the anal plates in the posterior interray of the dorsal cup. The described forms are distributed as follows: five in *Eupachycrinus* Meek and Worthen, of which one is new; eleven in *Phanocrinus* Kirk, of which six are new; three in *Pentaramicrinus* Sutton and Winkler, of which one is new; five in *Intermediacrinus* Sutton and Winkler, of which two are new; and nine in *Ageneracrinus* Sutton and Winkler, new collective group, of which seven species are new.

## GENERAL CONSIDERATIONS

IN THE August 1865 issue of the Proceedings of the Philadelphia Academy of Natural Sciences (not 1855 as commonly erroneously cited), Meek and Worthen proposed a new genus *Eupachycrinus*, with *Graphiocrinus quatuordecembrachialis* Lyon as the genotype. Lyon's description was so brief and relatively inadequate that they were undecided about the exact relationship of his type to other forms. They later said (1866, p. 177):

> For the present we place this group provisionally as a section of *Cyathocrinus*, though it is quite probable it will be found generically distinct both from that genus and *Poteriocrinus*.

Confusion as to the distinguishing features of *Eupachycrinus* has continued to the present. Characteristics, considered of sufficient value for generic differentiation in other groups, have been combined with the comment that this group represents a late stage in the history of the Cyathocrinidae and that these characters are scarcely of specific value in this exceptional case.

Wachsmuth and Springer (1879, p. 359) assigned various forms to the defined genus, *Eupachycrinus*. They said in their generic diagnosis:

> There are generally two arms to each ray or 10 to the individual; sometimes only five, as in *Eupachycrinus simplex*, Trautschold. . . . They are variously constructed, either of a single or double series of plates, . . . Anal plates generally three, rarely one; . . .

It is obvious that they were including in *Eupachycrinus* forms that we now know as *Eupachycrinus* Meek and Worthen, *Cromyocrinus* Trautschold, *Delocrinus* Miller and Gurley, *Erisocrinus* White, and *Phanocrinus* Kirk.

Later, the same authors (1886, p. 359) corrected their former grouping as follows:

> Accepting the genus *Cromyocrinus*, we have to consider only those species in which the cup is depressed or saucer-shaped, with small underbasals hidden from view and placed at the end of the basal concavity. These species, however, are divisible again into two groups; *a*, species with three azygous plates within the dorsal cup, *i.e.*, the typical form of *Eupachycrinus*, and, *b*, species with a small anal plate, partly extending into the equatorial regions, for which White proposed the genus *Ceriocrinus*.

They then proceeded to divide this last group on the relation of the single azygous plate to the radials. The forms in which it rests on the radials were placed under *Erisocrinus* White, and the remainder were assigned to *Ceriocrinus* (now known to be a synonym of *Delocrinus* Miller and Gurley).

They solved the problem of the number of arms as follows (1886, p. 173):

> Accepting also this division, and admitting into *Eupachycrinus* such species as "*Cromyocrinus*" *gracilis* Wetherby, which has but five arms, and *Eupachycrinus spartarius* Miller, with 14 arms, we must modify our former generic formula so as to admit species with five to 15 arms in place of 10, as we had previously given it.

The next person to make a division of those forms placed by Wachsmuth and

Springer under their restricted genus, *Eupachycrinus*, was Kirk (1937, pp. 598–607), who effected a division based upon a characteristic which had been used extensively for other groups but not for this one, the nature of the structure of the arms. He removed those with uniserial arms, restricting *Eupachycrinus* to forms with biserial arms and named the new uniserial-armed group *Phanocrinus*. Kirk included in *Phanocrinus* all forms with quadrangular arm ossicles, regardless of the number of arms. This is an important step toward the differentiation of *Eupachycrinus*-like forms in the light of modern biologic and taxonomic methods of classification and differentiation. However, there is still one more important criterion which has not been completely evaluated, the number of arms, and it is one of the purposes of this paper to complete the differential classification of the group included under *Phanocrinus* Kirk in so far as our knowledge of the forms permits.

Present difficulties in the classification of this group of crinoids arise because we are dealing with three changing features, none of which changes consistently or contemporaneously with the others. Due to poor correlations or differentiations of stratigraphic units, most of the specimens are said to have been procured from the "Kaskaskia" formation, a name now replaced by Chester series. Since it includes all Mississippian strata above the Ste. Genevieve limestone, the proper and exact stratigraphic location of many of the specimens has not been possible. These rocks contain varied *Eupachycrinus* and *Phanocrinus*-like forms.

The three parts of the crinoid which vary so in this limited stratigraphic range are the number of rami, the character of the rami, and the number of anal plates in the posterior interray of the dorsal cup. The number of rami varies from five in those forms with one ramus in each radius, through nine and 10, to 14 or more. Each ramus may be uniserial or biserial. However, there appears to be no mixing of the types in the same specimen in so far as *complete* arm units are concerned, with but one exception. This exception is *Eupachycrinus harii* Miller of the Pennsylvanian, which is said to have 18 rami, of which all but two, those of the anterior ray, are biserial. This is the only form known to the authors in which such a condition exists. This is an unusual form, having four rami in the other rays in which other known specimens have three as the maximum. It is an anomalous form and outside the scope of this paper, which deals only with Mississippian species.

The validity of a distinction between uniserial and biserial forms might be questioned because some otherwise biserial forms possess a few uniserial cuneate ossicles. We do not believe that this should cause any difficulties because these plates normally are restricted to the lower part of the arm, and beyond this the rami are definitely biserial. If the plates are cuneate for the entire length, they are either very cuneate or but slightly so. Those which are decidedly cuneate or wedge-shaped are assigned to the biserial group and the others to the uniserial. One exception to this general rule should be noted. *Intermediacrinus variabilis* Sutton and Winkler, n. sp., departs from the normal condition in one arm, the one on the left (pl. 67, fig. 11). The distal portion of this ramus is composed of 15 slightly cuneate ossicles, which extend entirely across the arm, a typically uniserial condition. The tapering of the arm suggests that these plates were very close to the end originally and that very little of it has been lost. It is suggested that if the entire arms of all biserial forms were known others might also end with uniserial plates. Probably this will never be tested thoroughly, because the delicate character of the arms usually results in the destruction of the distal extremities in preservation.

There should be no difficulty in distinguishing between the uniserial and biserial arm structure even of small or immature specimens, because none begin as uniserial forms and later change to biserial except in such cases as previously noted. There is a distinct differentiation of plates even in the immature individuals. This conclusion is the result of examination of several immature specimens, but further research may reveal some discrepancies.

The third feature, the number of anal plates in the dorsal cup, is closely knit into the complex of conditions arising from the other two factors. Examination of many specimens shows that none of the uniserial-

armed forms has less than three anal plates in the posterior interradius of the dorsal cup. Were it also true that a certain definite ramus number corresponded with this, there would remain no classification difficulties, but there may be five, nine, or 10 rami in the specimens with three anal plates and uniserial arms.

Another difficulty is encountered in the biserial-armed forms because this group contains some species with three anal plates and some with only two in the posterior interradius of the dorsal cup. Likewise, the number of rami differs for various forms. However, no observed specimen has biserial arm structure and 10 or less rami.

In summary it may be said that none of the observed specimens with uniserial arm structure has less than three anal plates in the dorsal cup and more than 10 rami. The biserial forms all possess more than 10 rami, but the number of anal plates in the dorsal cup may vary from three in some to two in other Mississippian species.

The completion of the classification of *Phanocrinus*-like forms necessitates the removal of the five-armed species placed in the genus by Kirk and a redefinition of it, using all characters. We have retained certain nine-armed forms in *Phanocrinus*, which might, upon superficial study, be considered sufficiently distinct for removal. Kirk made no disposition of them, although it is presumed that since he retained five-armed forms with the 10-armed that he would likewise include those with nine arms. These nine-armed forms are considered to be so closely allied to the 10-armed that it is unnecessary to place them in another genus. If there were a definite progression in arm number from five to nine, it would be impracticable to make the proposed division. However, since no six-, seven-, or eight-armed forms are known, it seems feasible and desirable to classify the uniserial forms into two genera, one with five arms, and one to include the nine- and 10-armed species.

Kirk described what appears to be *Phanocrinus gracilis* (Wetherby), from his description and figures, as *Phanocrinus formosus* (Worthen). This difficulty is removed by redescribing and figuring these species. A few other points should be noted. The figures and description which Kirk gives of *Eupachycrinus spartarius* Miller in his use of that species to represent a characteristic *Eupachycrinus*, are of a form other than *spartarius*, probably *Eupachycrinus irregularis*, a new species described in this paper. The form illustrated contains three anal plates in the dorsal cup, whereas the holotype of *Eupachycrinus spartarius* has but two and is placed by us in *Intermediacrinus*. Also, he leaves the impression in the discussion of his new genus *Ethelocrinus*, which contains *Eupachycrinus*-like forms with but two anal plates in the dorsal cup, that species with two anal plates are restricted to the Pennsylvanian and that they were derived from *Eupachycrinus* of the preceding period. It is probably true that *Ethelocrinus* was derived from an *Eupachycrinus*-like ancestor and does not occur in the Mississippian, but there are several Mississippian species with but two anal plates in the dorsal cup. These differ from *Ethelocrinus* in that anal *x* has not as yet migrated as far out of the dorsal cup as in that genus. In the Mississippian species anal *two* has migrated out of the dorsal cup but anal *x* has not as yet moved high enough to abut laterally both right and left posterior radials as it does in *Ethelocrinus*. Neither has the modification attained the stage where *anal two* is not in contact with the radianal, which is the condition in *Ethelocrinus*. This, therefore, represents a stage in the progression from forms with three anal plates in the dorsal cup to those in which but one or none remains. Species in this stage of the evolution of this group are placed in a new genus, *Intermediacrinus*.

It is desired to point out something else in connection with Kirk's paper. He states in his generic description of *Ethelocrinus* (1937, pp. 605–606) that the plates of the dorsal cup are

> covered with coarse granules that tend to become confluent.

It is questioned whether the ornamentation of the plates of the dorsal cup is of sufficient importance to be used as a generic determinant. This idea is well exemplified in a recent publication by Strimple (1938, pp. 11–12) wherein certain forms which lack this ornamentation are assigned to *Ethelocrinus*. There seems to be little doubt that they are

*Ethelocrinus* species, and it is considered that the definition should be altered to include these forms in the genus.

One other point should be emphasized. In the earlier days of descriptive paleontology, while materials were being gathered together, sorted, and crudely arranged, the grosser features were naturally made the basis for comparison and distinction. With increased information, it became necessary to pay attention to minor characters in order to get a well-developed and well-balanced degree of differentiation to suit the needs of faunal correlations and paleozoological phylogenetic relationships. Although the minor details have become of much more importance, the major features are still of great value although their analytical rank has changed. Whereas formerly they were the final or near final distinguishing characteristics, they are now among the first to be considered, and the minor details are the end product in so far as differentiation is concerned.

These ideas are substantiated by a study of the taxonomic history of any major group. As has been shown previously, the name *Eupachycrinus* has been applied to any crinoid with a certain well-developed type of dorsal-cup structure regardless of the number and character of arms. Kirk (1937, pp. 598–607) was the first to notice this unsatisfactory grouping of various forms, and *Phanocrinus* is the result. He based his differentiation between *Eupachycrinus* and *Phanocrinus* upon the structure of the arms, whether uniserial or biserial. In attempting to push his line of reasoning to its logical conclusion, one difficulty arises which, although of minor importance, must be corrected. Many of the forms previously assigned to *Eupachycrinus* were without a known arm-number or structure. As may readily be seen these are *incertae sedis* in so far as we are concerned with the present mode of classification. The only possibility for their identification lies in certain features of the dorsal cup as recognized in the restricted genera. If a certain feature occurred in one and only one of these circumscribed genera, it would be easy to place those forms with that cup feature in the proper genus whether or not the arms were known. However, no differentiating characteristic has been found constant for all forms. In fact, the dorsal cup, excluding the primibrachs in all cases as they are readily lost with the arms, of *Eupachycrinus germanus* Miller, a 14-armed, biserial form, can not be distinguished from that of *Pentaramicrinus gracilis*, which is a five-armed uniserial form. That this is not a new observation concerning the group is indicated by the following quotation from Wachsmuth and Springer (1879, p. 358):

> We have an example in a specimen from Kentucky, which we owe to the kindness of Prof. Wetherby, evidently *Eupachycrinus formosus* (*Zeacrinus formosus* Worthen), which in every other respect is so closely allied to *Eupachycrinus spartarius* S. A. Miller (which has two rows of alternating arm pieces), that the two cannot be separated unless the arms are preserved; . . . .

It may be noted as a point of interest that the two species can be distinguished by the position of the anal plates.

The preceding quotation serves to illustrate the point that unless arm number and structure are known, it is impossible to assign several of the dorsal cups to definite genera. Examination of the holotypes of most of the species originally assigned to *Eupachycrinus* shows that many Mississippian forms such as *Eupachcrinus crassus* Meek and Worthen, *E. monroensis* Worthen, *E. orbicularis* Hall, *E. subtumidus* Worthen, and *E. tumulosus* Miller, were named from dorsal cups alone, the arms being unknown. Although they have been termed *Eupachycrinus* in the past, that classification cannot now be justified because it is not possible to say with any degree of certainty or accuracy that the arm structure was biserial rather than uniserial. Since neither the name *Eupachycrinus* nor that of any other established genus can be sustained for these forms, it is necessary to redefine this group under a new name. It is for this group that the name *Ageneracrinus* is proposed. This is to be a collective group name for all of those forms in which a definite type of dorsal cup occurs, but for which no arms are known. If the primibrachs remain, it will be possible to determine the number of arms, and the form can be assigned to one of the genera erected for that number of arms. The question may be raised legitimately whether it is necessary to know

the arm structure in order to make the assignment to a certain genus. We believe not, because no forms with this type of dorsal cup are known with biserial arm structure and 10 or less arms. Likewise, none of the definitely uniserial specimens are known to have more than 10 arms.

*Eupachycrinus monroensis* Worthen has but one anal plate in the dorsal cup and therefore does not belong in any of the genera considered in this paper. The holotype of *Eupachycrinus orbicularis* (Hall) has not been examined, but illustrations of a paratype show that this species does not have a deep basal invagination. Since the infrabasals are visible in side view, it is tentatively referred to *Cromyocrinus*.

In the descriptions of species we have employed for different plates the letter symbols which are in common usage by most paleontologists. Some of the specimens which we are illustrating possess such close sutures that, although they are readily discernible under the binocular microscope, it has been necessary to retouch the photographs in order to make the plates stand out distinctly. The specimens described are in the paleontological collections of Walker Museum at the University of Chicago, the University of Illinois, and the Illinois State Museum of Natural History. We wish to express our thanks to Professor Carey Croneis and other officials of Walker Museum, and to Dr. Thorne Deuel of the Illinois State Museum for the opportunity of studying material from these institutions. The collection in which each specimen may be found is indicated in the text and illustrations.

## SYSTEMATIC DESCRIPTIONS

### Class CRINOIDEA Miller
### Order INADUNATA Wachsmuth and Springer
### Suborder FISTULATA Wachsmuth and Springer
### Family POTERIOCRINIDEA Roemer (emend. Wachsmuth and Springer)
### Genus EUPACHYCRINUS Meek and Worthen, 1865

*Eupachycrinus* MEEK and WORTHEN, *1865*, Acad. Nat. Sci. Philadelphia, Proc., p. 159; ——, *1866*, Illinois Geol. Survey, vol. 2, Paleontology, pp. 177, 178; WACHSMUTH and SPRINGER, *1880*, Revision of the Paleocrinoidea, pt. 1, pp. 133–139; ——, *1879*, Acad. Nat. Sci. Philadelphia, Proc., pp. 358–364; ——, *1866*, Revision of the Paleocrinoidea, pt. 3, sec. 2, p. 249; ——, *1886*, Acad. Nat. Sci. Philadelphia, Proc., p. 173; BATHER, *1900*, in Lankester, Treatise on Zoology, pt. 3, Echinoderma, p. 181; KIRK, *1937*, Jour. Paleontology, vol. 11, no. 7, pp. 598–599.

Column round in known species. Crown stout, compact, with heavy, relatively short rami. Dorsal cup bowl- to basin-shaped with deep basal invagination. IBB five, small, and hidden from side view in the basal invagination. BB five, large, hexagonal except the posterior and right posterolateral, which

---

EXPLANATION OF PLATE 66

All illustrations natural size unless otherwise indicated.

FIGS. *1, 2—Pentaramicrinus pulaskiensis* (Miller and Gurley), ×1.5. Anterior and posterior views of the holotype, Walker Mus., no. 6483. (p. 559)

*3–5—Intermediacrinus spartarius* (Miller). Posterior, anterior, and basal views of the holotype; Walker Mus., no. 6413. (p. 561)

*6, 7—Phanocrinus bellulus* (Miller and Gurley). Posterior and anterior views of the holotype; Walker Mus., no. 6278. (p. 554)

*8–10—Eupachycrinus irregularis* Sutton and Winkler, n. sp. Posterior, anterior, and basal views of the holotype; Walker Mus., no. 9418. (p. 551)

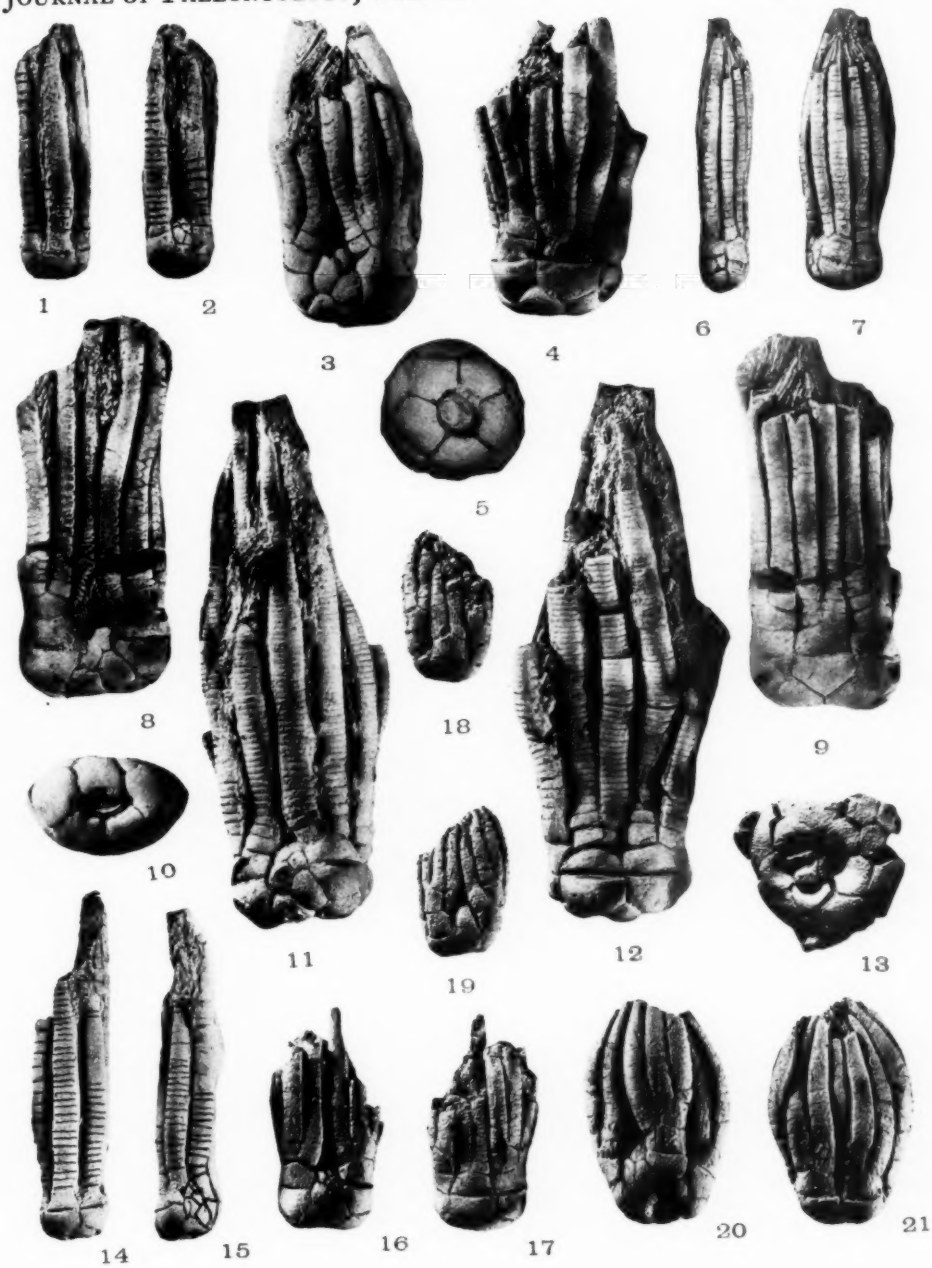
*11, 12—Phanocrinus cylindricus* (Miller and Gurley). Posterior and anterior views of a syntype; Walker Mus., no. 6412. (p. 553)

*13—Ageneracrinus parvaradianalis* Sutton and Winkler, ×2. Basal view of the holotype, somewhat crushed; Walker Mus., no. 30531. (p. 565)

*14, 15—Pentaramicrinus gracilis* (Wetherby). Anterior and posterior views of the holotype; Walker Mus., no. 6493. (p. 558)

*16, 17—Eupachycrinus germanus* Miller. Posterior and anterior views of the holotype; Walker Mus., no. 6411. (p. 551)

*18–21—Eupachycrinus durabilis* (Miller and Gurley), ×1.5. *18, 19*, Anterior and posterior views of a syntype; Walker Mus., no. 6482; *20, 21*, Oblique posterior and anterior views of a hypotype, Walker Mus., no. 9412. (p. 549)




Sutton and Winkler, Mississippian Crinoids

are heptagonal. In this and other described genera, the number of facets may appear to be one less on each basal unless the basal-infrabasal sutures are visible. The posterior and right posterolateral basals support the anal plates. The inferior portion of each plate curves inward to form the invagination. RR five, broader than high with the greatest width along the superior surface.

Three anal plates in the posterior interray of the dorsal cup. RA pentagonal, rests upon the posterior and right posterolateral basals, and supports rt and anal *x*. Anal *x* rests on the posterior basal and abuts rt, RA, and the left postero-lateral radial. The rt rests upon the radianal and against the right posterolateral radial and anal *x*.

IBr large, pentagonal, each supporting two IIBr. The anterior IIBr bears two rami. In other rays the anterior half usually bifurcates on the IIBr, giving three rami in a radius, thus producing a total of 14 arms in most species. The rami are relatively short, stout, and compactly biserial. The arm ossicles bear stout pinnules. This genus differs from the closely related *Intermediacrinus* and *Ethelocrinus*, in which genera only two anal plates are in the dorsal cup.

*Genotype.*—*Graphiocrinus quatuordecembrachialis* Lyon.

*Remarks.*—This genus includes the American species *quatuordecembrachialis, durabilis, germanus, variabilis* and probably *boydii*. The crinoids from China which Tien referred to *Eupachycrinus* do not seem to belong in this genus.

### EUPACHYCRINUS QUATUORDECEMBRACHIALIS (Lyon)

*Graphiocrinus 14 brachialis* LYON, *1857*, Kentucky Geol. Rept., vol. 3, p. 477, pl. 1, figs. 2–2b.

*Eupachycrinus 14-brachialis* (Lyon) MEEK and WORTHEN, *1865*, Acad. Nat. Sci. Philadelphia Proc., ser. 1, vol. 17 (ser. 2, vol. 9), p. 159, *1866*, Illinois Geol. Survey, Paleontology, vol. 2, sec. 2, p. 177.

*Eupachycrinus quatuordecembrachialis* (Lyon) WACHSMUTH and SPRINGER, *1879*, Acad. Nat. Sci. Philadelphia, Proc., p. 363; ——, *1880*, ibid., Revision of the Paleocrinoidea, pt. 1, p. 139; S. A. MILLER, *1883*, The American Palaeozoic fossils, supplement to first edition (called second edition on title page), p. 282; S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 266; KIRK, *1937*, Jour. Paleontology, vol. 11, no. 7, pp. 599–601, pl. 84, figs. 4–7.

Dorsal cup smooth, low, bowl-shaped, about one-half as high as wide. IBB of the holotype detached and probably in the dorsal cup. BB five, quite tumid, with about one-half their length involved in the basal invagination. Each B has a median groove in that portion involved in the pit. Plates hexagonal, except the posterior and right posterolateral which are heptagonal. The right posterolateral and posterior BB support the RA between them and the posterior B supports anal *x* superiorly. RR, pentagonal, about two-thirds as high as wide with the greatest width along the superior edge. RA large, pentagonal, and about one-half as wide as long. Anal *x* is pentagonal, about two-thirds as large as the radianal, and rt is nearly as large as anal *x*.

IBr large, pentagonal, about one-half as high as wide. The anterior plate is the largest, and the right and left posterolateral ones are somewhat smaller than the others. Each plate has a tumid boss below the point of contact between the secundibrachs borne by that plate. There are 14 compactly biserial arms in this species, with three in all but the anterior radius, which has but two. The upper portion of the arm is broken away, but the arms taper as though they were not very long. This species is characterized by the relative shapes and sizes of the plates in the dorsal cup together with the 14 arms and the produced character of the IBr. No specimens have been available for illustrations.

*Type.*—Holotype from the Chester of Crittendon County, Kentucky, and is no. S3817 in the Springer collection of the U. S. National Museum.

*Remarks.*—*Cyathocrinus? pentalobus* Hall is listed by S. Weller in his "Bibliographic Index of North American Carboniferous Invertebrates" as a synonym of *Eupachycrinus quatuordecembrachialis*. These forms are considered to be different and are herein assigned to two genera. *Quatuordecembrachialis* is retained in *Eupachycrinus* and *pentalobus* is placed in *Intermediacrinus*.

### EUPACHYCRINUS DURABILIS (Miller and Gurley)

Plate 66, figures 18–21

*Zeacrinus durabilis* MILLER and GURLEY, *1895*, Illinois State Mus. Nat. History, Bull. no. 6,

p. 48, pl. 4, figs. 14–15; S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 651.

*Eupachycrinus durabilis* (Miller and Gurley) SUTTON and HAGAN, *1939*, Jour. Paleontology, vol. 13, no. 1, p. 83.

This is a small, somewhat barrel-shaped species. Dorsal cup low, basin-shaped, about one-third as high as wide. IBB hidden beneath the column. BB about as high as wide, and although but slightly involved in the basal invagination, are scarcely visible in side view because of the basin shape of the dorsal cup. RR nearly twice as large as the basals, pentagonal, with the greatest extension along the superior edge. RA elongate, narrow, about one-half as wide as long, and pentagonal. Anal *x* hexagonal and about two-thirds as large as the radianal. The rt plate hexagonal and about equal in size to anal *x*.

IBr pentagonal, large, about as high as the dorsal cup, and three-fourths as high as wide. All bear three arms except the anterior, which has but two. The IIBr in the anterior position in each radius bearing three arms is large, as high as wide, and bears two rami. Arms short, about five times the height of the dorsal cup, tapering very much, and composed of cuneate to interlocking ossicles. The lower arm plates are least cuneate but become more cuneate in a distal direction, changing from plates extending entirely across the arms in the lower portions to definitely biserial structure at some distance from the arm bases. This species is distinguished by its smallness, the shape and relative size of the dorsal cup, and the character of the arms.

*Type.*—Syntypes are no. 6482 in the Gurley collection of the University of Chicago and were collected from the Chester series in Sloans Valley, Pulaski County, Kentucky. The illustrated hypotype is no. 9412 in the Gurley collection and was collected from the Chester series in Pulaski County, Kentucky.

### EUPACHYCRINUS? BOYDII Meek and Worthen
### Plate 67, figures 16, 17

*Eupachycrinus boydii* MEEK and WORTHEN, *1870*, Acad. Nat. Sci. Philadelphia, Proc., p. 30; *1873*, Illinois Geol. Survey, vol. 5, p. 554, pl. 21, fig. 6; S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 266; E. WOOD, *1909*, U. S. Nat. Mus., Bull. 64, p. 95, pl. 7, figs. 1–5.

Dorsal cup bowl-shaped, rounded above and below with the greatest width near the top of the basals, and smooth, with well defined sutures. Cup about 2½ times as wide as high, with fairly large basal invagination. IBB dropped into the basal invagination. BB normal for the genus, about one-half as wide as long, with about one-third their length involved in the basal invagination. Each B possesses a central groove throughout the portion in the basal invagination. This groove enlarges into a pit about halfway to the base of the invagination. RR pentagonal, three-fifths as high as wide with the greatest width at the point of junction of two radials and the superior tip of a basal. There are probably three anal plates in the dorsal cup although the holotype specimen retains only anal *x*. RA probably roughly pentagonal, anal *x* pentagonal, about one-half as large as the radianal space and about one-half in the cup. The rt plate likewise missing.

Three IBr preserved in the holotype. Each is pentagonal, about one-third as high as wide, and supports two IIBr of which the posterior position bears one arm and the anterior two in so far as can be determined. This form very probably possessed 14 arms, which is the usual number for the genus. The arms are broken, but their bases show that they are stout and compactly biserial. This species is characterized by the rounding of the dorsal cup above, causing it to be narrower at the top of the RR than at the bottom. Likewise, the grooves with the pitlike enlargement in the BB are useful for identification.

*Type.*—Holotype from the Chester series near Chester in Randolph County, Illinois, and is no. X-138 in the paleontological collection at the University of Illinois.

*Remarks.*—The holotype is broken, leaving but the anterior, left anterolateral and left posterolateral regions. Although RA is missing, this form is thought to have had three anal plates in the dorsal cup, since the position and shape of anal *x* are the same as for other *Eupachycrini*. The specimen illustrated by E. Wood is evidently not *boydii*, but possibly a specimen of *Intermediacrinus tumidus*.

EUPACHYCRINUS GERMANUS Miller
Plate 66, figures 16, 17

*Eupachycrinus germanus* MILLER, *1879*, Cincinnati Soc. Nat. History, Jour., vol. 2, p. 40, pl. 8, fig. 3.
*Eupachycrinus spartarius* (Miller) S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 266.

Dorsal cup smooth, bowl-shaped, about one-half as high as wide, with basal invagination concealing the infrabasals from side view. IBB small and sunken in the basal invagination. BB nearly as wide as high, with about one-third their lengths involved in the basal invagination. RR pentagonal, about one-half as high as wide, with greatest width along the superior edge. There are three anal plates in the dorsal cup. RA pentagonal, elongate, narrow, about one-half as wide as long; anal *x* hexagonal, about one half as large as the radianal; and rt pentagonal and about one-half as large as anal *x*. Approximately one-half of anal *x* is in the cup, and about one-fifth of the rt plate is below the radial-primibrach suture. IBr pentagonal, about one-half as high as wide, the two posterior slightly larger than the others. All bear three arms except the anterior, which has but two. The anterior IIBr in each radius except the anterior is enlarged, about as high as wide, and bears two rami. This makes 14 arms in this species. Arms stout, compact, biserial, about four times as long as the height of the dorsal cup, and with long, stout pinnules. This form is distinguished by the relative shape of the crown. It was referred to by Weller as a synonym for *spartarius* but is here considered to be distinct.

*Type.*—Holotype from the Chester series of Pulaski County, Kentucky, and is no. 6411 of the Gurley collection at the University of Chicago.

EUPACHYCRINUS IRREGULARIS
Sutton and Winkler, n. sp.
Plate 66, figures 8–10

Dorsal cup smooth, low bowl-shaped, about one-half as high as wide. IBB small, pentagonal, extending slightly beyond the proximal columnal. BB about as high as wide, hexagonal, except the posterior and and right posterolateral which are heptagonal, and with about one-fifth the length involved in the basal invagination. RR larger than the basals, pentagonal, about two-thirds as high as wide, with the greatest width along the superior edge. RA large, pentagonal, about four-fifths as wide as long. Anal *x* pentagonal, about two-thirds as large as RA, and with about one-half its length in the cup. The rt plate is pentagonal, smaller, and half in the cup.

IBr large, pentagonal, about three-fifths as high as wide, each supporting two IIBr. The anterior IIBr in the right and left anterolateral radii support two arms, each producing three rami to each of these rays. The posterior IIBr of the left posterolateral ray supports two arms, producing three rami in this ray also. The anterior and right posterolateral IBr support but two rami each, making a total of 13 arms in the species. The rami begin with uniserial cuneate plates which change to compactly biserial at the third or fourth. Rami are about six times the height of the dorsal cup. Each ramus bears long stout jointed pinnules.

This species is characterized by the large size, shape, and relationship of the anal plates to each other and to the other plates of the dorsal cup, and the irregular development of the arms. This may be the form described and figured by Kirk (1937, pp. 601–602, pl. 84, figs. 8–14) as a typical *Eupachycrinus spartarius* Miller.

*Type.*—The type specimen came from the Chester series (probably Glen Dean limestone) of Pulaski County, Kentucky, and is no. 9418 in the Gurley collection at the University of Chicago.

Genus PHANOCRINUS Kirk, 1937
(emend. Sutton and Winkler)

*Phanocrinus* KIRK, *1937*, Jour. Paleontology, vol. 11, no. 7, p. 602.

This genus differs mainly from *Eupachycrinus* in the structure of the arms. In *Eupachycrinus*, as redefined, the rami are relatively short, stout, biserial, and composed of cuneate ossicles. In *Phanocrinus* they are uniserial and composed of quadrangular plates. Kirk included both five- and 10-armed species in the genus. However, in order to carry the classification to a logical conclusion, it seems better to make a separation based upon the number of arms. Since *Zeacrinus formosus* Worthen, Kirk's genotype, has 10 rami, those with five rami,

such as *Cromyocrinus gracilis* Wetherby, are to be removed from *Phanocrinus* and made a separate genus. This necessitates a redefinition of *Phanocrinus*.

Dorsal cup low, shallow, bowl- to basin-shaped, broader than high with a fairly deeply invaginated base, smooth, with somewhat tumid plates. Crown long, stout, compact. Arms unbranched, uniserial, pinnulate, 10, or in some species, nine, in number. Column slender, circular, with small axial canal. Dicyclic. IBB small, pentagonal, five in number, and completely in the basal invagination. BB five, fundamentally hexagonal, except the posterior and right posterolateral which are heptagonal. They curve sharply inward to form the dorsal invagination. In this genus as well as in the other genera and the collective group discussed in this paper, the BB of many species appear pentagonal or hexagonal instead of hexagonal or heptagonal when the basal-infrabasal sutures are not exposed. However, when the plates are disarticulated it is evident that there are two facets on the dorsal side of each B rather than one curved facet. The apparent absence of two *sharply delimited* facets on this part of the BB is most pronounced in those species in which the IBB have become fused into a pentagonal disk. It is quite probable that in previous descriptions of specimens of this group of crinoids in which BB are said to be pentagonal that they are in reality hexagonal, but because of inability to see clearly the facets of the lower side of the BB they have been called pentagonal. RR five, pentagonal except the right posterolateral which in some species is four-sided, convex outward, greatest width along the superior surface, about two-thirds as high as wide. Each ray, except the anterior in some species and the left posterolateral in one, contains one axillary, pentagonal IBr, about one-half as high as broad, which rests on the truncated upper surface of a radial. The IBr, which supports but one arm in the nine armed forms, is quadrangular. The IIBr are quadrangular, gradually becoming smaller distally.

The anal area contains three plates, a radianal, anal *x*, and the right tube plate, in the dorsal cup. RA long, narrow, usually pentagonal and completely in the cup. It is truncated on the inferior edges by two BB, on the right by a radial, on the left by anal *x*, and on the superior surface by rt. Anal *x* is about one-half as large as the RA, usually hexagonal, although pentagonal in some species, bounded dorsally by a basal, on the right by the RA and rt, above by a tube plate, and on the left by a radial and a primibrach. Its lower half is usually within the dorsal cup. The second anal plate is smaller than anal *x*, usually hexagonal, ventral to

EXPLANATION OF PLATE 67

All illustrations natural size unless otherwise indicated.

FIGS. *1, 2—Intermediacrinus asperatus* (Worthen). Posterior and anterior views of the holotype, Illinois State Mus., no. 2443. (p. 561)

*3, 4—Phanocrinus maniformis* (Yandell and Shumard), ×1.5. Posterior and anterior views of a hypotype; Walker Mus., no. 19133. (p. 554)

*5, 6—Phanocrinus fragosus* Sutton and Winkler, n. sp., ×1.5. Anterior and posterior views of the holotype; Walker Mus., no. 30083. (p. 557)

*7, 8—Phanocrinus compactus* Sutton and Winkler, n. sp. ×1.5. Anterior and posterior views of the holotype; Walker Mus., no. 30244. (p. 555)

*9, 10—Phanocrinus parvaramus* Sutton and Winkler, n. sp. Posterior and anterior views of the holotype; Walker Mus., no. 9414. (p. 556)

*11—Intermediacrinus variabilis* Sutton and Winkler, n. sp. Oblique basal view of the holotype; Walker Mus., no. 39404. (p. 562)

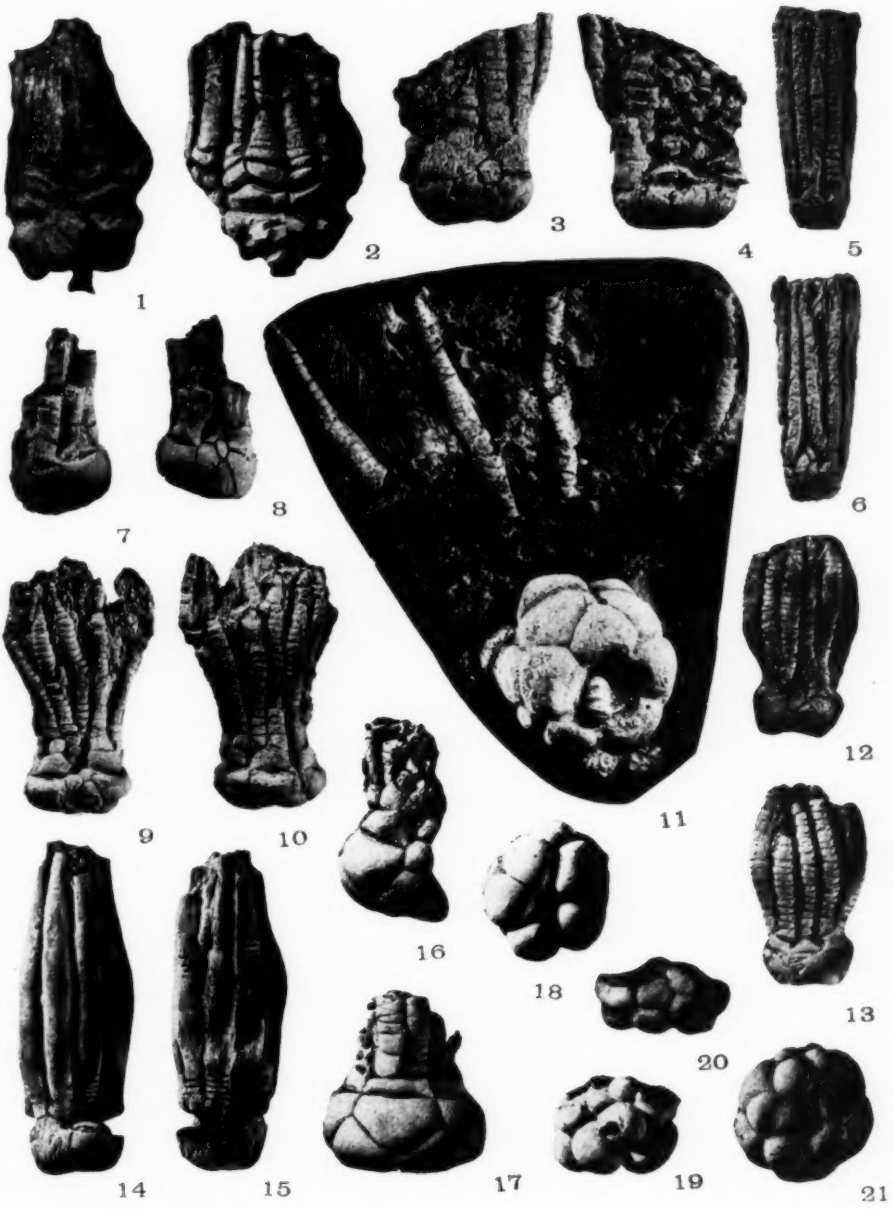
*12, 13—Phanocrinus nitidus* (Miller and Gurley). Posterior and anterior views of the holotype; Walker Mus., no. 19131. (p. 555)

*14, 15—Phanocrinus inflatoramus* Sutton and Winkler, n. sp. Anterior and posterior views of the holotype; Walker Mus., no. 9416. (p. 555)

*16, 17—Eupachycrinus boydii* Meek and Worthen. Posterior and left lateral views of the holotype; Illinois Univ., no. X-138. (p. 550)

*18, 19—Ageneracrinus tumulosus* (Miller). Basal and posterior views of the holotype; Walker Mus., no. 6240. (p. 563)

*20, 21—Ageneracrinus subtumidus* (Worthen). Posterior and basal views of the holotype; Illinois Univ., no. X-842. (p. 563)




Sutton and Winkler, Mississippian Crinoids

the radianal and dorsal to a second tube plate, bordered on the right by a radial and primibrach and on the left by anal *x* and tube plate, and usually with about one-half or less of its length in the cup.

*Genotype.*—*Zeacrinus formosus* Worthen.

*Remarks.*—This genus as restricted will contain the genotype *Zeacrinus formosus* Worthen, and the following species, *cylindricus*, *maniformis*, *bellulus*, and *nitidus* of the heretofore described forms, and the new species *inflatoramus*, *compactus*, *parvaramus supratumulosus*, *fragosus*, and *petalloformis*. Of these, *inflatoramus*, *compactus*, and *nitidus* are nine-armed while *bellulus* and *maniformis* are very probably so. The species with five rami, which definitely seem to indicate an evolutional and developmental stage nonconjunctive with that of *Phanocrinus*, are classified in the new genus, *Pentaramicrinus*. This is such a distinct, clean-cut form that no one should have any difficulty in distinguishing it from other genera.

PHANOCRINUS FORMOSUS (Worthen)
Plate 68, figures 17–19

*Zeacrinus formosus* WORTHEN, *1873*, Illinois Geol. Survey, vol. 5, p. 549, pl. 21, fig. 2.
*Eupachycrinus formosus* WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 264.
*Phanocrinus formosus* KIRK, *1937*, Jour. Paleontology, vol. 11, no. 7, p. 603, pl. 84, figs. 1, 2.

Basin-shaped dorsal cup with a flattened base. Basal invagination involves one-fourth to one-third of the BB. IBB small, and extend beyond the proximal columnal. BB of nearly the same height and width, moderately tumid, fundamentally hexagonal, except the right posterolateral and posterior which are heptagonal. RR pentagonal, except the right posterolateral which is four-sided, with the longest side for the articulation with the primibrach. The RR are about three-fifths as high as wide with the greatest width at the point of articulation with the IBr. The RA is pentagonal and moderately large. Most of anal *x* is missing from the holotype but probably it was pentagonal or hexagonal and about one-half the size of the RA. The right posterolateral R is somewhat mashed in the type specimen, but judging from the height and position of the left posterior R, there were three anal plates in the dorsal cup, although nothing can be determined as to the size and shape of rt. Three radii of the type specimen bear two uniserial rami each with a single axillary IBr. The remainder of the specimen is broken away. Surface of all plates covered with fine, nonconfluent granules.

*Type.*—Holotype is no. X-817 of the Worthen collection of the University of Illinois. Collected from the Chester series at Chester, Randolph County, Illinois.

PHANOCRINUS CYLINDRICUS
(Miller and Gurley)
Plate 66, figures 11, 12

*Zeacrinus cylindricus* MILLER and GURLEY, *1894*, Illinois State Mus. Nat. History, Bull. 5, p. 38, pl. 3, figs. 19–21.
*Phanocrinus cylindricus* SUTTON and HAGAN, *1939*, Jour. Paleontology, vol. 13, no. 1, p. 83.

Dorsal cup moderately low, basin-shaped. IBB small, and extending beyond the proximal columnal. BB slightly longer than wide, curving inward and upward abruptly into the basal invagination for about one-third their length. The middle part of each B is depressed before uniting with the IBB plates. Three BB are hexagonal and two, the posterior and right posterolateral are heptagonal, although, because the sutures at the dorsal ends are invisible, each appears to possess one facet less. The three posterior BB are slightly larger than the two anterior, with the right posterolateral the largest. RR pentagonal, about two-thirds as high as wide, with the greatest width at the top. The RA is moderately large and pentagonal. Anal *x* is pentagonal and about two-thirds as large as the RA. The rt plate is pentagonal and about one-half the size of anal *x*.

There are five pentagonal IBr nearly twice as wide as high with the greatest width along the inferior edge. Each supports two long, subfusiform, uniserial, unbranched rami. The length of the arms is about eight times the height of the dorsal cup. The arm ossicles are short, quadrangular, and bear short, stout pinnules. Although Miller and Gurley described it as having a granular surface, this is not evident on the syntypes. This form can be distinguished from *Phanocrinus formosus*, which is com-

posed of plates covered with fine to medium-sized nonconfluent granules. Also the basal plates of *Phanocrinus formosus* are not depressed before they join the infrabasals as in *Phanocrinus cylindricus*.

*Type*.—The syntypes are no. 6412 of the Walker Museum collection. They were obtained from the Chester series of Pulaski County, Kentucky.

### PHANOCRINUS MANIFORMIS
(Yandell and Shumard)
Plate 67, figures 3, 4

*Cyathocrinus maniformis* YANDELL and SHUMARD, *1847*, Contributions to the geology of Kentucky, p. 25, pl., fig. 2.
*Poteriocrinus maniformis* SHUMARD, *1855*, Missouri Geol. Survey, Ann. Rept., p. 217.
*Zeacrinus maniformis* HALL, *1858*, Iowa Geology, vol. 1, pt. 2, p. 682, pl. 25, fig. 8.
*Scytalocrinus maniformis* WACHSMUTH and SPRINGER, *1879*, Acad. Nat. Sci. Philadelphia, Proc., p. 340.
*Eupachycrinus maniformis* WACHSMUTH and SPRINGER, *1886*, Acad. Nat. Sci. Philadelphia, Proc., p. 173; KEYES, *1894*, Missouri Geol. Survey, vol. 4, p. 217; WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 265; E. WOOD, *1909*, U. S. Nat. Mus., Bull. 64, p. 94, pl. 11, fig. 4.

Dorsal cup bowl-shaped, about twice as wide as high. IBB small. The lower one-third of the BB inflected sharply to form the basal invagination. BB normal for the genus. The RR are pentagonal and about as high as wide. The RA is pentagonal and of medium size. Anal *x* is pentagonal and nearly as large as the radianal. It supports rt and lt. The rt is hexagonal and nearly as large as anal *x*. The IBr are about one-half as high as wide and each supports two uniserial rami except the left posterolateral, which bears but one ramus, making a total of nine arms. The rami are about six times the height of the dorsal cup.

*Type*.—Holotype from the Chester limestone at Chester, Illinois, and a plasto-hypotype is no. 15854 in the James Hall collection of Walker Museum at the University of Chicago. The illustrated hypotype was collected from the Chester series at Dover Hill, Martin County, Indiana and is no. 19133 in the Gurley collection in Walker Museum.

*Remarks*.—We are in considerable doubt as to the exact characters of this species. We have not been able to examine the holotype but have seen a plasto-hypotype on which the characters are not well displayed. Earlier descriptions vary, some designating it as a nine-armed and others as a 10-armed form. Illustrations likewise are of little value. The hypotype which we have illustrated, while not a particularly good specimen, appears to show most of the essential characters. It appears to possess 10 arms. The new species *P. parvaramus* Sutton and Winkler possesses arms quite similar to *maniformis* and is definitely 10-armed. The specimen described by Wood (1909, p. 94, pl. 11, fig. 4) does not seem to be *maniformis* because the elongation of the radianal is from posterior basal to right posterolateral radial rather than from right posterolateral basal to anal *x* as is the position in the plasto-hypotype and hypotype which we have examined. Its exact identity is not determinable from the description and one figure.

### PHANOCRINUS BELLULUS
(Miller and Gurley)
Plate 66, figures 6, 7

*Zeacrinus bellulus* MILLER and GURLEY, *1894*, Illinois State Mus. Nat. History, Bull. 3, p. 34, pl. 3, fig. 8; WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 650.
*Scytalocrinus? bellulus* SUTTON and HAGAN, *1939*, Jour. Paleontology, vol. 13, no. 1, p. 83.

Small, slightly constricted above the IBr. Dorsal cup basin-shaped. Surface granular. Moderately deep basal invagination. IBB small. BB so completely in the invagination that only the tops are visible in side view. The holotype does not exhibit all of the basals, but it is presumed that they are the same as in other species, namely, three hexagonal and two heptagonal.

RR pentagonal, about three-fourths as high as wide, with the longest edge the articulation for the primibrachs. RA elongate, narrow, and pentagonal. Anal *x* hexagonal and nearly as large as the RA. The rt pentagonal and smaller.

The IBr are pentagonal, rather large, nearly as large as the radials, and three-fourths as high as wide. Each IBr appears to bear two uniserial rami composed of nearly quadrangular to slightly cuneate arm pieces. However, since the anterior radius is not visible and there are only nine

arms showing superiorly, it is quite possible that there are only nine arms in this species. The rami are about six times as long as the height of the dorsal cup. This species is quite distinct because the BB are so pronouncedly involved in the basal invagination and the IBr are practically as large as RR.

*Type.*—The holotype was collected from the Chester series near Shoals, Martin County, Indiana, and is no. 6278 of the Gurley collection at the University of Chicago.

### PHANOCRINUS NITIDUS
(Miller and Gurley)
Plate 67, figures 12, 13

*Zeacrinus nitidus* MILLER and GURLEY, *1894*, Illinois State Mus. Nat. History, Bull. 3, p. 36, pl. 6, figs. 3, 4; WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 652.
*Phanocrinus nitidus* SUTTON and HAGAN, *1939*, Jour. Paleontology, vol. 13, no. 1, p. 83.

Species small, constricted at the primibrachs. Surface granular. Dorsal cup bowl-shaped. IBB small and fallen into the basal invagination. BB plates normal, as high as wide, about one-fourth in the basal invagination. RR pentagonal, and three-fifths as high as wide, with the greatest width at the top. The RA is fairly large and quadrangular, abuts against the posterior and right posterolateral BB below and against the right posterolateral radial and anal *x* above. Anal *x* hexagonal and rests upon the radianal, posterior basal, and left posterolateral radial. The rt plate is missing in the holotype but was evidently quite small and almost out of the cup.

The IBr are pentagonal except the anterior, which is quadrangular, and are about four-fifths as high as wide. With the exception of the anterior, which supports but one ramus, each IBr supports two short stout uniserial rami composed of cuneiform ossicles. The nine rami in this species are about four times as long as the height of the dorsal cup. The short, relatively large rami and the peculiar anal interray are characteristic.

*Type.*—The holotype is no. 19131 of the Gurley collection at the University of Chicago and came from the Chester series of Randolph County, Illinois.

### PHANOCRINUS COMPACTUS
Sutton and Winkler, n. sp.
Plate 67, figures 7, 8

Dorsal cup small, sutures very well closed. IBB hidden by the column. BB normal. About one-half of each basal plate is involved in the basal invagination. The sutures are so closely knit that a side view gives a perfectly smooth surface where the plates turn inward. RR pentagonal, superior edge longest, about three-fifths as high as wide, and curved in such a manner that the superior side of the dorsal cup turns inward, forming nearly a semicircle from the basal invagination to the superior edge of the radials. The RA is large and pentagonal. Anal *x* is hexagonal and slightly smaller than the radianal, with about three-fourths of its length in the cup. The rt is elongate and pentagonal, with about one-half its length in the cup.

IBr five, pentagonal, except the anterior, which is quadrangular. Their heights are nearly equal to their widths. Two arms in each ray except the anterior, which has but one. Each ramus is composed of a single series of quadrangular ossicles. The upper portions of the rami of the holotype are broken away so it is not possible to determine the original length. Because of the small size of the ossicles it is presumed that the arms were not very long. In this specimen the ventral sac protrudes above the broken arms. It is about twice as thick as an arm and enlarges gradually until it is terminated in a blunt end with five small protuberances. This species is characterized by the closely knit plates, the shape of the dorsal cup, and the shape of the plates of the anal interray.

*Type.*—The holotype came from the Golconda limestone near Golconda, Illinois, and is no. 30244 in the Walker Museum collection.

### PHANOCRINUS INFLATORAMUS
Sutton and Winkler, n. sp.
Plate 67, figures 14, 15

Dorsal cup bowl-shaped, sutures distinct, plates smooth, with no protuberant edges. IBB small, hidden. BB normal with about one-half of each plate in the invagination. RR pentagonal, about two-thirds as high as wide, with the greatest width along the

superior edge at the point of articulation with the primibrachs. The right posterolateral radial, radianal, and anal 2 are missing in the holotype. The RA has been lost but the cavity remaining indicates that it must have been five- or six-sided and but slightly larger than anal *x*. Anal *x* is hexagonal and half in the cup.

Only two IBr are preserved. The anterior is quadrangular and supports one ramus. The right anterolateral is pentagonal, three-eighths as high as wide, and bears two rami. The spaces formerly occupied by the other primibranchs show that they were like the right anterolateral. This is a nine-armed species. The rami are composed of narrow quadrangular ossicles with very close, smooth sutures. Each ramus widens gradually from the proximal attachment to the midpoint of its length and then steadily but rapidly tapers to the end. At the point of maximum width each ramus is from five-eighths to three-fourths as wide as the primibrach, which produces a peculiar barrel-shaped appearance. The extreme width of the IBr as compared to their height and the inflated character of the rami are the main diagnostic features of this species.

*Type*.—The holotype came from the Chester series of Pulaski County, Kentucky, and is no. 9416 of the Gurley Collection of Walker Museum.

PHANOCRINUS PARVARAMUS
Sutton and Winkler, n. sp.
Plate 67, figures 9, 10

Dorsal cup low, saucer-shaped, about three eighths as high as wide and composed of slightly tumid, smooth plates. IBB small and hidden beneath the proximal columnal. BB slightly tumid, about two-thirds as wide as high with about one-third their length in the shallow basal invagination. RR much more tumid than the basals, about three-fourths as high as wide with the greatest width slightly below the superior edge. RA very large, pentagonal, fairly tumid, about two-thirds as wide as long. Anal *x* pentagonal, nontumid, about one-half as large as the radianal and very narrow where it joins the posterior basal, being so acute dorsally as to appear four-sided rather than five-sided. The rt hexagonal, about one-half as large as anal *x*, and about one-third in the cup.

IBr pentagonal, about one-half as high as wide, with the greatest width along the inferior edge. Each supports two short, uniserial arms composed of somewhat tumid, rounded ossicles, which bear elongate jointed pinnules. Arms about four times the height of the dorsal cup, nearly uniform for about two-thirds their lengths and then tapering very rapidly to a point. This species is characterized by the shape of the dorsal cup, the very acute anal *x*, the tumid character of the radials as compared to the other plates of the cup, and the length and character of the rami.

*Type*.—The holotype was collected from the Chester series, probably Glen Dean formation, of Pulaski County, Kentucky, and is no. 9414 of the Gurley collection, the University of Chicago.

PHANOCRINUS SUPRATUMULOSUS
Sutton and Winkler, n. sp.
Plate 68, figures 9, 10

Dorsal cup high, bowl-shaped with very tumid basals. All plates of dorsal cup smooth. IBB fused into a somewhat tumid, pentagonal disk protruding beyond the small proximal columnal. BB protuberant, occupying about two-thirds the entire height of the cup, fundamentally hexagonal and heptagonal but appearing to possess one facet less on each, because of the almost continuous curvature of the dorsal side where it is in contact with the infrabasal disk. RR pentagonal, about one-half as high as wide, with greatest width along the superior surface. They exhibit greatest tumidity in the central portion and slope off to the edges. The anal plates cannot be completely determined in this specimen.

IBr pentagonal, about three-fifths as high as wide, somewhat tumid with greatest tumidity across the base and at the superior end, where they form a nodelike structure. In so far as can be determined from the holotype there are 10 rami composed of quadrangular ossicles. The specimen is somewhat broken, leaving the IBB, BB, some of the RR and IBr, and a few of the arms.

The characteristics of this form are the protuberant, smooth basals and the peculiar

radials and primibrachs. It varies from the nearest described form, *Ageneracrinus tumidorugosus*, in the lack of ornamentation of the basals and the character of the primibrachs and from *Ageneracrinus tumulosus* (Miller) in the character of the fused infrabasal disk and shape of the basals.

*Type.*—The holotype was collected from the Chester series of Randolph County, Illinois, and is no. 19132 in the Gurley collection of the University of Chicago.

*Remarks.*—It may seem questionable whether this can be ascribed to *Phanocrinus*, but we believe so because no uniserial forms of this general character are known with but two anal plates in the dorsal cup. Likewise, since each of the two preserved primibrachs gives rise to two rami, it is believed that this was a nine- or 10-armed species, and its assignment to that genus is indicated. Since *A. tumidorugosus* and *A. tumulosus* bear such a close resemblance to this species, it would seem probable that they belong in the same genus, but because no arm structure is known for them they are assigned to *Ageneracrinus*.

PHANOCRINUS PETALLOFORMIS
Sutton and Winkler, n. sp.
Plate 68, figures 5, 6

Dorsal cup smooth, low, bowl-shaped, about one-half as high as wide, with nontumid plates. IBB and columnals lost from the holotype. IBB were small and probably hidden in the basal invagination beneath the proximal columnal. BB about three-fourths as wide as high, with about one-fourth their length in the basal invagination. Each has a depression in the center where it bends into the concavity. RR pentagonal, about two-thirds as high as wide, with the greatest width along the superior edge. RA large, pentagonal, and about three-fifths as wide as long. Anal *x* hexagonal, about two-thirds as large as RA, and with about one-half its length in the cup. The rt plate is pentagonal, about two-thirds as large as anal *x* and with about one-third its length in the cup.

IBr pentagonal, about three-fourths as wide as high, greatest width along the inferior edge. They are sharply constricted about midway of the length. The left posterolateral IBr is missing from the holotype, but each of the other four bore two uniserial arms composed of quadrangular ossicles. Since in this genus, the ray that possesses only one arm in the nine-armed forms is, with the exception of *P. maniformis*, the anterior, and because this form possessed two arms in the anterior ray, it is presumed that it was a 10-armed species. The most diagnostic features of this species are the sharply constricted IBr, the deep invagination, the relative size of the BB, and their depressed shape where they enter the basal concavity, and the size of the RR.

*Type.*—The holotype was collected from the Paint Creek shale, one and one-fourth miles northwest of Floraville, Illinois, by Stuart Weller. It is no. 26923 in the Weller collection of Walker Museum.

PHANOCRINUS FRAGOSUS Sutton
and Winkler, n. sp.
Plate 67, figures 5, 6

Small species with dorsal cup smooth, low, bowl-shaped, about one-half as high as wide. IBB hidden beneath the proximal columnal. BB nearly as wide as high and typical of the genus. RR pentagonal, about one-half as high as wide, with the greatest width along the superior surface. RA small, pentagonal, about twice as long as wide. Anal *x* about the same size and with about two-thirds its length in the cup. The rt plate is pentagonal, about two-thirds as large as anal *x*, and with nearly half the length in the cup.

IBr five, pentagonal, about two-thirds as wide as high, supporting two rami each. The right and left posterolateral and the anterior IBr are about one-third longer than the right and left anterolateral plates. Rami short, about five times the height of the dorsal cup, 10 in number, each composed of one series of slightly cuneate ossicles, which bear long stout pinnules. This form is characterized by its small size, the shortness of the arms, the small radianal, and the character of the primibrachs.

*Type.*—The holotype and paratypes are no. 30083 of the Walker Museum collection and were obtained from the Renault limestone three miles east of Waterloo, Illinois.

### Genus PENTARAMICRINUS Sutton and Winkler, n. gen.

Dorsal cup smooth, moderately low, shallow, bowl- to basin-shaped, broader than high with a deeply invaginated base. Crown long, slender, compact. Arms five, unbranched, uniserial, and pinnulate. Column slender, circular. Dicyclic. The five IBB form a pentagonal disk but do not extend beyond the proximal columnal. BB five, hexagonal except the posterior and right posterolateral which may vary, although they are usually heptagonal. In most specimens the BB appear pentagonal and hexagonal because of the nearly arcuate character of the two inferior basal facets. This is especially so if the basal-infrabasal sutures are hidden by the column. However, insofar as we know, the BB are always fundamentally hexagonal except the posterior and right posterolateral which possess more than six facets. BB curve sharply inward to form the dorsal invagination. RR five, pentagonal, slightly convex outwards, greatest width along the superior surface, about one-half as high as wide. The first brachial is elongate, quadrangular, and about one-third as high as wide. The remaining brachials are quadrangular, gradually enlarging to a point near the middle of each ramus and then slightly but gradually becoming smaller distally. The arm ossicles bear stout pinnules alternating on each side. The anal area of the dorsal cup contains three plates, RA, anal *x*, and rt plate. The RA is variable in shape, truncated on its inferior edges by one or two BB, on the right by a radial, on the left by anal *x*, by the left posterolateral radial, or both, and on its ventral surface by the rt plate. Anal x is less than two-thirds as large as the RA, bounded on the left by a radial, at the upper left by a primibrach, to the right by RA and rt, and may or may not be in contact with a basal below. It is nearly half included in the dorsal cup. The rt plate is slightly smaller than anal *x*, has a small portion of the dorsal half of the plate in the dorsal cup, and is bounded inferiorly by RA, to the left by anal *x* and a tube plate, and to the right by the right posterolateral radial and primibrach.

The characteristic feature of this genus which differentiates it from the closely related genus *Phanocrinus* Kirk is that it contains but five rami, one in each radius. The dorsal cup is higher than that of *Phanocrinus* and may be best described as bowl-shaped.

*Genotype.*—*Cromyocrinus gracilis* Wetherby.

### PENTARAMICRINUS GRACILIS (Wetherby)
Plate 66, Figures 14, 15

*Cromyocrinus gracilis* WETHERBY, *1880*, Cincinnati Soc. Nat. History, Jour., vol. 2, p. 248, pl. 16, figs. 2–2e; W. A. MILLER, *1883*, The American Paleozoic fossils, 2d edition, p. 281.
*Eupachycrinus gracilis* WACHSMUTH and SPRINGER, *1886*, Revision of the Paleocrinoidea, pt. 3, sec. 2, p. 249; *1886*, Acad. Nat. Sci. Philadelphia, Proc., p. 173.
*Phanocrinus gracilis* KIRK, *1937*, Jour. Paleontology, vol. 11, no. 7, p. 606, pl. 84, fig. 3.

Dorsal cup bowl-shaped, about one-half as high as wide. IBB small and hidden beneath the column. Basal invagination involves about one-third of the BB, which are normal for the genus and nearly as high as wide. RR about two-thirds as high as wide and with the IBr articulation facet extending the entire width of the plate. The RA is moderately large, pentagonal, and nearly twice as long as wide, and is in contact with two basals. Anal *x* is hexagonal, smaller than the RA, more than half in the cup, and in contact with the posterior basal. The rt plate is hexagonal, about two-thirds as large as anal *x*, with about one-third of the length in the cup. Two additonal tube plates are exposed in the posterior interray of the holotype.

Each ray is a single long, stout arm, composed of essentially quadrangular ossicles, which bear stout alternating pinnules.

The first IBr is relatively large, elongate, two-thirds as high as wide, and non-axillary. The rami increase in width to a point about one-third their length and then decrease slightly in size. They are about 10 times as long as the height of the dorsal cup.

The specimens studied are those of the Gurley collection at Walker Museum and the University of Illinois collection, and one obtained by Stuart Weller, which is also from Walker Museum. Those of the Gurley collections came from the Chester series of Pulaski County, Kentucky, and that of Stuart Weller from the Golconda limestone

one mile north of Ruma, Illinois.

*Type.*—Holotype is no. 6493 of the Gurley collection, Walker Museum.

PENTARAMICRINUS MAGNARADIANALIS
Sutton and Winkler, n. sp.
Plate 68, figures 24, 25

Dorsal cup moderately low, bowl-shaped, broader than high, with deeply invaginated base. IBB small and hidden beneath the proximal columnal. The BB are more than one-fourth in the basal invagination. They are of nearly the same height and width, except the right posterolateral and right anterolateral, which are somewhat larger. All BB hexagonal except the right posterolateral, which is heptagonal. Anal *x* does not contact the basals. RR pentagonal except the left posterolateral, which is hexagonal, nearly twice as wide as high, with greatest width along the superior surface. The RA is very large, hexagonal, more than twice the size of anal *x*. It abuts the posterior basal and left posterolateral radial on the left and the right posterolateral basal and radial upon the right. It supports anal *x* and rt. Anal *x* is small, pentagonal, abutting against the radianal and left posterolateral radial and only about one-fourth in the cup. The rt plate is much smaller and extends only a very short distance into the cup.

Each ray consists of a single stout arm. The first IBr is large, and its distal face sloping. The arm ossicles are quadrangular. This species differs from *Pentaramicrinus gracilis* (Wetherby) in possessing a much larger RA, which does not assume the same position with respect to the surrounding plates.

*Type.*—The holotype is no. 39353 of the Gurley collection at the University of Chicago and came from the Chester series of Pulaski County, Kentucky.

PENTARAMICRINUS PULASKIENSIS
(Miller and Gurley)
Plate 66, figures 1, 2

*Zeacrinus pulaskiensis* MILLER and GURLEY, *1895*, Illinois State Mus. Nat. History, Bull. no. 3, p. 47, pl. 4, figs. 12, 13; WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 652.

Dorsal cup bowl-shaped, about one-half as high as wide. IBB hidden beneath the column. Basal invagination involves about one-third of the BB, which are nearly the same height and width, and hexagonal except the posterior, which is heptagonal. The posterior is the only one in contact with any anal plates. RR pentagonal, about two-thirds as high as wide, with the primibrach articulation facet extending the entire width of the plate. The RA is quadrangular, small, and about one-half the length of anal *x*. It rests on the posterior basal, abuts anal *x* on the left, the right posterolateral radial on the right, and supports the rt. Anal *x* is hexagonal, about twice as long as wide, considerably wider toward the top, and about two-thirds in the cup. It rests upon the superior face of the posterior basal. The rt plate is smaller, pentagonal, and about one-third in the cup.

Each ray bears a single relatively stout arm. The first primibrach is rather large, elongate, slightly longer than wide, and nonaxillary. The rami increase in size to a point about two-fifths their length, beyond which they decrease in size and taper to a blunt point. The quadrate ossicles bear pinnules. The rami are about eight times as long as the height of the dorsal cup. This form differs from *Pentaramicrinus gracilis* in the relative positions and sizes of anal and basal plates.

*Type.*—The holotype was obtained from the Chester series (probably the Glen Dean limestone) at Sloan's Creek, Pulaski County, Kentucky, and is no. 6483 of the Gurley collection of the University of Chicago.

Genus INTERMEDIACRINUS Sutton
and Winkler, n. gen.

Dorsal cup moderately low, bowl- to basin-shaped with relatively flat base and a tendency to constriction at the arm bases. The basal invagination obscures the infrabasals in side view. Plates convex and may or may not be covered with granules or pustules. IBB five, forming a pentagon, sometimes extending beyond the proximal columnal. BB five, fairly large, hexagonal, except the posterior and right posterolateral, either or both of which may be heptagonal or octagonal. Each plate may appear to possess one less facet than the actual number if the inferior edges are not visible. RR low and broad, with the articulating facets occupy-

ing the entire width of the plates.

There are two anal plates in the dorsal cup, RA and anal *x*. RA large, commonly pentagonal, resting usually on the posterior and right posterolateral basals, and supporting anal *x* and the rt plate, which is out of the cup. In one species RA is not in contact with the right posterolateral basal. Only one-fifth or less of its length extends above the radial-primibrach suture. Anal *x* usually hexagonal, resting upon the posterior B and RA and laterally abutting against the left posterolateral R, RA, and a tube plate. It is situated with about the lower half in the cup.

Rami compact, stout, biserial, varying in number, although 14 seems to be normal. Column circular in cross section.

*Genotype.*—*Eupachycrinus asperatus* Worthen.

*Remarks.*—It is difficult to select a genotype species for this genus. Only two of the described species, *spartarius* and *asperatus*, have complete crowns, and neither of these possesses features which are best suited for this purpose. *Spartarius*, which has arms and plates whose general characters are similar to most members of this group, has a radianal which is not in contact with the right posterolateral basal. *Asperatus* has a radianal which is more normal, in contact with both posterior and right posterolateral basals, but the general character of the plates is not typical of these forms because of the development of angular protuberances on many of them. The irregular number of arms in the different rays is also not typical. Because we believe that the genotype should be a form as complete as possible and because most of the described species assigned to this genus possess radianals in contact with two basals, we have selected *asperatus* rather than *spartarius* as the genotype, even though the general character of the plates and the arm development are not typical. We feel that the typical arrangement of anal plates in *asperatus* is of more significance than the irregularities mentioned above.

This genus is considered one of an evolutionary series leading from the five-armed, uniserial forms with three anal plates in the dorsal cup to the 12- to 18-armed, biserial forms with but one anal plate in the cup. The main differentiation between this genus and *Ethelocrinus* is that anal *x* has risen in the dorsal cup of *Ethelocrinus* until it is bounded by both the right and left posterolateral radials. In *Intermediacrinus*, anal *x* has not risen sufficiently high to be bounded by both

---

EXPLANATION OF PLATE 68

All illustrations natural size unless otherwise indicated.

FIGS. *1, 2—Ageneracrinus basalis* Sutton and Winkler, ×2. Basal and posterior views of the holotype Walker Mus., no. 19137. (p. 564)

*3, 4—Ageneracrinus parvabasalis* Sutton and Winkler, ×2. Posterior and basal views of the holotype; Walker Mus., no. 19135. (p. 565)

*5, 6—Phanocrinus petalloformis* Sutton and Winkler, *5*, ×2; *6*, ×1.5. Basal and posterior views of the holotype; Walker Mus., no. 26923. (p. 557)

*7, 8—Ageneracrinus altacalyx* Sutton and Winkler, ×2. Basal and posterior views of the holotype; Walker Mus., no. 39406. (p. 565)

*9, 10—Phanocrinus supratumulosus* Sutton and Winkler, Posterior and basal views of the holotype; Walker Mus., no. 19132. (p. 556)

*11, 12—Intermediacrinus pentalobus* (Hall). Posterior and basal views of the holotype; Illinois Univ., no. X-841. (p. 562)

*13, 14—Ageneracrinus platycalyx* Sutton and Winkler, ×2. Basal and posterior views of a syntype; Walker Mus., no. 26791. (p. 564)

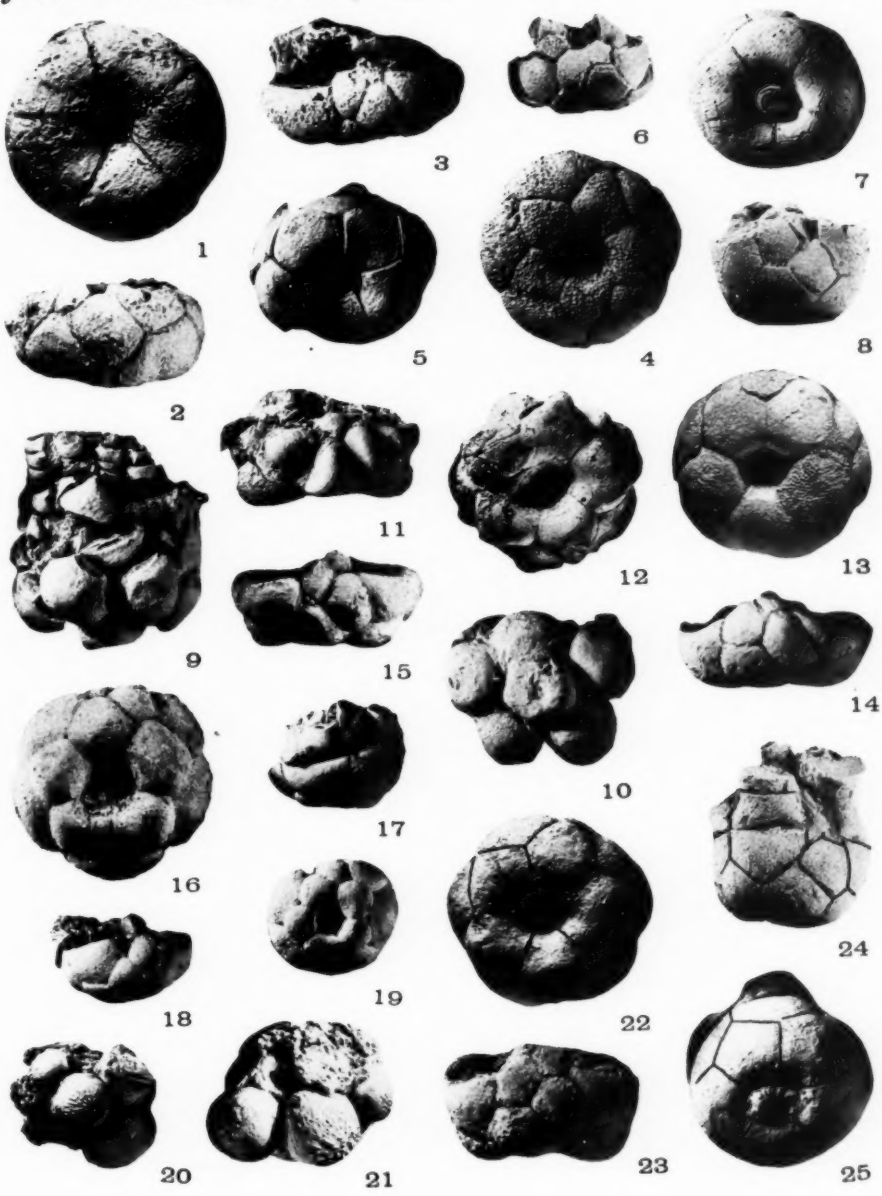
*15, 16—Intermediacrinus tumidus* Sutton and Winkler, ×2. Posterior and basal views of the holotype; Walker Mus., no. 19134. (p. 561)

*17–19—Phanocrinus formosus* (Worthen). Anterior, posterior, and basal views of the holotype; Illinois Univ., no. X-817. (p. 553)

*20, 21—Ageneracrinus tumidorugosus* Sutton and Winkler. Posterior and basal views of the holotype; Walker Mus., no. 39346. (p. 566)

*22, 23—Ageneracrinus basalotumidus* Sutton and Winkler, ×2. Basal and posterior views of the holotype; Walker Mus., no. 9430. (p. 565)

*24, 25—Pentaramicrinus magnaradianalis* Sutton and Winkler, ×2. Posterior and basal views of the holotype; Walker Mus., no. 39353. (p. 559)




Sutton and Winkler, Mississippian Crinoids

UNIV. OF MICH.

radials. The radianal extends above the right posterolateral radial.

In this genus we are placing the following species: *asperatus*, *spartarius*, *pentalobus*, *tumidus*, and *variabilis*.

### INTERMEDIACRINUS ASPERATUS (Worthen)
Plate 67, figures 1, 2

*Eupachycrinus asperatus* WORTHEN, *1882*, Illinois State Mus. Nat. History, Bull. 1, p. 34; *1883*, Illinois Geol. Survey, vol. 7, p. 311, pl. 29, fig. 4; S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 264.

Dorsal cup of medium size, bowl-shaped, about one-half as high as wide, with tumid angular plates. IBB concealed beneath the column. BB hexagonal, except the posterior and right posterolateral which are heptagonal, extended into angular protuberances above the basal pit. Right posterolateral basal supports RA on the left side, and the posterior basal supports RA and anal *x*. BB about two-thirds as wide as high with about one-third their length in the basal pit. RR pentagonal, except the right posterolateral, which is quadrangular, about one-half as high as wide, and each extended inferiorly into an angular protuberance. RA pentagonal, elongate, about one-half as wide as long, and angularly protuberant centrally, Anal *x* small, about one-third as large as the radianal, and about one-half in the cup.

IBr five, pentagonal, about one-third as high as wide, with angular protuberance near the central superior part. Each supports two IIBr. The three anterior rami bear two arms each. The right posterolateral radius bears four arms and the left posterolateral three. This gives 13 biserial arms, which taper rapidly toward their extremities. The location of the angular nodes on the BB, RR, and IBr together with the shape and nature of the anal plates, the depressions in the basals, and the arm numbers are all characteristic of this species.

*Type*.—The holotype is no. 2443 of the Illinois State Museum of Natural History and came from the Chester series of Monroe County, Illinois.

### INTERMEDIACRINUS SPARTARIUS (Miller)
Plate 66, figures 3, 5

*Eupachycrinus spartarius* S. A. MILLER, *1879*, Cincinnati Soc. Nat. History, Jour., vol. 2, p. 38, pl. 8, fig. 2; S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 266; KIRK, *1937*, Jour. Paleontology, vol. 11, no. 7, pp. 601–602, pl. 84, figs. 8–14.

Dorsal cup bowl-shaped, about one-third as high as wide, smooth, with convex plates. IBB dropped out of sight in the basal invagination. BB hexagonal except the posterior, which is heptagonal, with an arcuate right superior facet. BB nearly as high as wide, with about one-fourth their length involved in the basal invagination. RR pentagonal, about two-thirds as high as wide, with the greatest width along the superior edge. The posterior-lateral RR are shortened somewhat to allow for the insertion of the anal plates. RA quadrangular, resting one arcuate-shaped side upon the posterior basal while it abuts anal *x* and the right posterolateral radial laterally and supports rt but does not contact the right posterolateral basal. Anal *x* as large as the radianal, pentagonal, and about one-half in the cup. The rt plate rests upon the RA and lies completely out of the dorsal cup.

IBr pentagonal, about one-half as high as wide, and support two IIBr each. The anterior IIBr in each arm except in the anterior ray is much larger than the other and supports two arms, whereas the smaller supports but one. The anterior radius has two arms. This makes 14 arms in this species. Arms stout, compactly biserial, tapering very slightly. The tips of all the arms are broken away in the type specimen. Each arm ossicle bears a long, slender pinnule. This species is characterized by the shape and size of the anal plates and their relationship to the dorsal cup.

*Type*.—The holotype came from the Chester series of Pulaski County, Kentucky, and is number 6413 of the Gurley collection at the University of Chicago.

### INTERMEDIACRINUS TUMIDUS Sutton and Winkler, n. sp.
Plate 68, figures 15, 16

Dorsal cup low, saucer-shaped, about one-third as high as wide, with the greatest width at the center of the radial plates. All plates smooth and tumid, although anals *x* and two are but slightly so. IBB small and hidden in the basal invagination by the proximal columnal. BB all nearly the same size, about

two-thirds as wide as high, with about one-third their length in the basal invagination. The posterior and right posterolateral ones are heptagonal and the others hexagonal. RR pentagonal except the right posterolateral, which is quadrangular, about two thirds as high as wide with their tops curving inward so that a flattening of the dorsal cup results. RA large, pentagonal, about twice the size of anal *x*, which is pentagonal and sitting about one-half in the cup. The rt plate is quite small and completely out of the dorsal cup. Column and arms unknown.

This species is characterized by the lack of angularity of the tumid plates, the general shape of the dorsal cup, and the character of the anal plates. It resembles most nearly *Ageneracrinus basalotumidus* Sutton and Winkler, from which it differs in having but two anal plates in the cup.

*Type.*—The holotype is no. 19134 of the Walker Museum collection and was obtained from the Renault limestone four and one-half miles southwest of Red Bud, Illinois.

### Intermediacrinus variabilis Sutton and Winkler, n. sp.
Plate 67, figure 11

Dorsal cup smooth, bowl-shaped, about one-third as high as wide, with a deeply invaginated base. IBB hidden in the basal invagination. BB somewhat tumid, protruding out as far as the greatest extension of the radials, nearly as wide as high, with about one-third of their lengths in the basal invagination. The central portion of that part of each basal which is in the invagination is depressed. RR pentagonal except the right posterolateral, which is rudely quadrangular, about two-thirds as high as wide, with the greatest width at the superior edge. RA very large, pentagonal, moderately tumid, and about two-fifths as wide as long. Anal *x* small, roughly pentagonal, and about two-fifths as large as the radianal. The rt plate is nearly the same size as anal *x* and entirely out of the cup.

The arms of the holotype are broken loose and lie outspread beside the calyx. Three IBr are preserved. Each is somewhat tumid and low, about one-third as high as wide, and bears two superior facets. Remains of four moderately large arms are embedded in the matrix. Each is compactly biserial except for the last 15 ossicles of the arm on the left, which extend completely across the arm. The length and lack of tapering, except in this arm, indicate that they were fairly long. A portion of the column, which is moderately large and composed of alternating large and smaller round ossicles, remains. This species is characterized by the general shape of the dorsal cup and the nature of the anal plates.

*Type.*—The holotype is no. 39404 of the Walker Museum collection and was obtained from the Paint Creek formation at Columbia, Illinois.

### Intermediacrinus pentalobus (Hall)
Plate 68, figures 11, 12

*Cyathocrinus? pentalobus* Hall, *1858*, Iowa Geology, vol. 1, pt. 2, p. 687, pl. 25, figs. 5a, b.
*Eupachycrinus quatuordecembrachialis* Weller, *1898*, U. S. Geol. Survey, Bull. 153, p. 266.

Dorsal cup almost rectangular in side view. All plates of the cup extremely produced in the center but meeting normally at the margins. These protuberances become crudely angular in the extensions of the basal plates but remain rounded in the anal and radial plates. Basal invagination very large and deep. IBB small, pentagonal, extending beyond the proximal columnal. BB hexagonal, except the posterior and right posterolateral, which are heptagonal. The right posterolateral supports RA upon the left and the posterior bears RA upon the right superior sloping shoulder and anal *x* superiorly. BB about one-third involved in the basal invagination. As they emerge from the basal pit, they become greatly protuberant. RR hexagonal, except the right posterolateral, which is roughly quadrangular, nearly as high as wide, with the greatest width along the superior edge, produced greatly near the central superior part. RA pentagonal and very long, with the width about one-half the length. Anal *x* small, hexagonal, about one-third the size of RA, slightly tumid, and about two-thirds in the cup. Column and arms unknown.

This species is characterized by the very broad and deep basal depression, the angularly produced BB and rounded protuberant RR and RA. It was considered to be synonymous with *E. quatuordecembrachialis*

by Stuart Weller in U. S. Geol. Survey, Bull. 153, but we find that they are completely distinct.

*Type.*—Holotype is no. X-841 in the University of Illinois collection and came from the Chester series, Pope County, Illinois.

### Collective Group AGENERACRINUS Sutton and Winkler, nom. nov.

Dorsal cup low, shallow, bowl- to basin-shaped, broader than high, with a fairly deeply invaginated base, smooth with somewhat tumid to very tumid plates. Crown unknown. Dicyclic. IBB five, small and hidden in the basal invagination in side view. BB five, fundamentally hexagonal, except the posterior and right posterolateral which are heptagonal. Superficially, they appear pentagonal and hexagonal if the lower facets are not visible. This is especially true in those forms in which the IBB have fused into a disk with the development of more or less arcuate sides. A portion of the BB is involved in the basal invagination. RR five, usually pentagonal, although the right posterolateral may vary from this shape, convex outward, with greatest width along the superior surface, wider than high. Parts of three anal plates in the dorsal cup. RA as large or larger than either of the other two. Anal *x* in most forms rests upon the left superior sloping shoulder of RA. The rt plate rests upon the right superior sloping shoulder of anal *x* and on RA.

IBr and arms unknown. Because of the absence of these elements it is not possible to assign these forms to any of the described genera.

*Remarks.*—That there shall be no question concerning the validity of such a designation as we propose, attention is called to the first recommendation of Article eight in the General Considerations of the International Rules of Zoological Nomenclature which states:

> Certain biological groups which have been proposed distinctly as collective groups, not as systematic units, may be treated for convenience as if they were genera, but they require no type species.

Moore (1938, pp. 175–189) recently has employed this method of classification for fragmentary crinoidal remains, chiefly individual plates of various types. We are confining it to more or less complete dorsal cups. Moore's scheme of classification utilizes the terms group and section for taxonomic units comparable in rank to genus and species respectively. Types were designated for sections but not for groups, in harmony with the Rules of Nomenclature. The same general plan of classification is followed in this paper.

The following forms are assigned to this collective group: *subtumidus*, *tumulosus*, *platycalyx*, *basalis*, *basalotumidus*, *parvabasalis*, *altacalyx*, *parvaradianalis*, and *tumidorugosus*. All but the first two are new.

### AGENERACRINUS SUBTUMIDUS (Worthen) Plate 67, figures 20, 21

*Zeacrinus subtumidus* WORTHEN, *1873*, Illinois Geol. Survey, vol. 5, p. 548, pl. 21, fig. 1.
*Eupachycrinus subtumidus* WELLER, U. S. Geol. Survey, Bull. 153, p. 268.

Dorsal cup bowl-shaped, about one-third as high as wide. IBB small, almost hidden in the basal concavity by the column. BB normal for the group, nearly as wide as high, protuberant, with about one-fourth their length involved in the basal invagination. RR pentagonal, about one-half as high as wide, with the greatest length along the superior surface, tumid but not protuberant. The RA is fairly large, protuberant, and hexagonal. Anal *x* is hexagonal, very tumid, about three-fourths as large as the radianal, and with nearly two-thirds of its length in the cup. The rt plate is hexagonal, strongly tumid, nearly as large as anal *x*, and is situated with the lower half in the dorsal cup. IBr, rami, and column unknown. Surface of plates without ornamentation. This form can be recognized by the protuberant BB and RR and relative sizes and shapes of the anal plates.

*Type.*—The holotype is from the Chester series near Bay City, Pope County, Illinois, and is no. X-842 in the Worthen collection at the University of Illinois.

### AGENERACRINUS TUMULOSUS (Miller) Plate 67, figures 18, 19

*Eupachycrinus tumulosus* MILLER, *1891*, Indiana Geol. Survey, 17th Rept., Advance Sheets, p. 70, pl. 9, figs. 9, 10; ——, *1892*, idem., p. 680, pl. 9, figs. 9, 10; WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 266.

Dorsal cup bowl-shaped, about one-half

as high as wide with the greatest width near the top of the basals. All plates of the dorsal cup covered with fine granules. IBB fused to form a small, flat, pentagonal disc, which lies completely in the basal invagination. BB very protuberant, with greatly depressed sutures. They form two-thirds the height of the dorsal cup and are unequal in size, with the right posterolateral about half larger than any of the others, and the posterior the smallest. The junctions between facets are more or less rounded, producing an outline which lacks the angulations of most species. RR pentagonal, slightly tumid, about one-third as high as wide, with the greatest length along the superior edge. RA pentagonal, very large and protuberant, nearly as large as a radial. Anal *x* is small, about one-fourth as large as RA and somewhat tumid. It is pentagonal, rests upon RA and against the left posterolateral radial, and wedges down between them to touch the posterior basal. More than one-half is in the cup. The rt plate is about the same size and shape as anal *x* but is less than one-half in the cup.

IBr, rami, and column unknown, although the cicatrix on the IBB indicates that the column was round and very small, about 2 mm. in diameter and less than one-half the diameter of the infrabasal disk. This form is characterized by the large tumid BB, their size, relationships, and the size of RA with respect to the other anal plates. Its resemblances and possible relationships to *Phanocrinus supratumulosus* and *Ageneracrinus tumidorugosus* have been discussed elsewhere.

*Type.*—The holotype is from the Chester series of Breckenridge County, Kentucky, and is no. 6240 in the Gurley collection at the University of Chicago.

AGENERACRINUS PLATYCALYX Sutton and Winkler, new section

Plate 68, figures 13, 14

Dorsal cup low, basin-shaped, scarcely one-third as high as wide, plates slightly tumid, with no markings. IBB small, pentagonal, hidden under column in basal invagination. Length and width of BB about equal, with about one-fourth their length involved in the dorsal invagination. The posterior basal extends somewhat higher in the cup than do the others. RR pentagonal, about one-half as high as wide, with the greatest length along the superior surface. The RA is pentagonal, about one-half as wide as long. Anal *x* is hexagonal, about one-half as large as RA, with approximately one-half its length in the cup. The rt plate is pentagonal, about one-half the size of anal *x*, and with only about one-third of its length in the cup. The very low, saucer-shaped dorsal cup and the narrow, elongate RA are the main diagnostic features of this form.

*Types.*—The syntypes are from the Shetlerville member of the Renault limestone one-half mile south of Eichorn, Illinois, and are no. 26791 of the Walker Museum collection at the University of Chicago.

AGENERACRINUS BASALIS Sutton and Winkler, new section

Plate 68, figures 1, 2

Dorsal cup smooth, bowl-shaped, about one-half as high as wide, RR curving inward as much as do the BB before they enter the basal invagination. IBB very small, hidden under column in basal invagination. BB very large, about as wide as high, not tumid, with about one-fourth their length in the basal invagination. RR pentagonal, about three-fifths as high as wide, with the greatest width slightly below the superior edge, unequal in size, with the left and right posterolateral ones smaller than the others. RA very large, pentagonal, about four-fifths as wide as long. Anal *x* pentagonal, about one-fourth as large as RA, and almost entirely in the cup. The rt plate is missing from the holotype, but the space between anal *x*, RA, and the right posterolateral radial suggests a small plate that was probably hexagonal and longer than wide. IBr, rami, and column unknown. This form is characterized by the shape of the dorsal cup, with the incurving RR, the large size of the BB and the relative sizes of the anal plates.

*Type.*—Holotype is from the Chester series of Prarie du Long Creek, St. Clair County, Illinois, and is no. 19137 of the Gurley collection of Walker Museum, at the University of Chicago.

AGENERACRINUS BASALOTUMIDUS
Sutton and Winkler, new section
Plate 68, figures 22, 23

Dorsal cup smooth, bowl-shaped, about one-third as high as wide. IBB small, hidden beneath the column in the basal invagination. BB moderately tumid, about five-sixths as wide as high, with about one-third their length in the basal invagination. RR pentagonal, larger than the basals, two-thirds as high as wide, with the greatest width along the superior edge. RA pentagonal, slightly tumid, and about three-fifths as wide as long. Anal *x* hexagonal, about three-fourths as large as RA, and two-thirds in the cup. The rt plate is slightly smaller than anal *x*, hexagonal, and about one-half in the cup. The protruding tumid basals and the relative sizes of the anal plates are the characteristic features of this form.

*Type.*—The holotype was collected from the Chester series of Union County, Illinois, and is no. 9430 in the Gurley collection of Walker Museum at the University of Chicago.

AGENERACRINUS PARVABASALIS
Sutton and Winkler, new section
Plate 68, figures 3, 4

Dorsal cup low, basin-shaped, smooth, one-third as high as wide. IBB relatively large, pentagonal, extending beyond the column in the basal concavity. BB small, the posterior and right posterolateral somewhat larger than the others, about as wide as high, with about one-fourth their length involved in the basal concavity, hexagonal, except the posterior and right posterolateral which are heptagonal. RR somewhat tumid, pentagonal, about two-thirds as high as wide, with the greatest width along the superior edge. RA pentagonal, about two-thirds as wide as long at the greatest width, and tapering in both directions. Anal *x* hexagonal, about two-thirds as large as RA, with nearly two-thirds of its length in the cup. The rt plate is hexagonal, about one-half as large as anal *x*, and has about one-third of its length in the cup. This form is characterized by the shape of RA, the petaloid shape of the BB, and the large, tumid RR.

*Type.*—Holotype from the Chester series (probably Glen Dean) of Sloan's Valley, Kentucky, and is no. 19135 of the Gurley collection of Walker Museum at the University of Chicago.

AGENERACRINUS ALTACALYX
Sutton and Winkler, new section
Plate 68, figures 7, 8

Dorsal cup smooth, deeply bowl-shaped, about one-half as high as wide, with deep basal invagination. IBB small and hidden beneath the column in the basal invagination. BB hexagonal, except the posterior and right posterolateral, which are heptagonal, nearly as high as wide, with about one-fourth their length in the basal invagination. RR pentagonal, about two-thirds as high as wide, with the greatest extension along the superior surface. RA large, pentagonal, three-fourths as wide as long. Anal *x* pentagonal and nearly as large as the radianal, with three-fourths of its length in the cup. The rt plate is almost entirely missing from the holotype. It was probably hexagonal, slightly smaller than anal *x*, and with about one-half its length in the cup. Column round and composed of alternating small and larger ossicles. This form is characterized by the depth of the dorsal cup and the size of the anal plates.

*Type.*—The holotype is from the Chester series of Randolph County, Illinois, and is no. 39406 in the Gurley collection of Walker Museum at the University of Chicago.

AGENERACRINUS PARVARADIANALIS
Sutton and Winkler, new section
Plate 66, figure 13

Dorsal cup low, basin-shaped, about one-half as high as wide, with fine irregular to confluent reticulae covering the non-tumid plates. IBB hidden beneath the columnal in the basal invagination. BB hexagonal, except the posterior and right posterolateral, which are heptagonal, small, about two-thirds as wide as high, with more than one-third their length in the basal invagination. There is a depression in the center of each basal where it curves into the concavity. RR pentagonal, about one-half as high as wide, with the greatest width along the superior edge. RA small, pentagonal, and about one-half as wide as long. Anal *x* hexagonal, slightly larger than the radi-

anal, and with slightly less than one-half of its length in the cup. The rt plate is hexagonal, only slightly smaller than anal *x*, and only slightly in the cup. Characteristic features of this form are the ornamentation of the plates and the relative approximate sizes of the anal plates.

*Type.*—The holotype was collected from the Golconda limestone five miles north of Marion, Kentucky, and is no. 30531 of the Walker Museum collection.

### AGENERACRINUS TUMIDORUGOSUS
Sutton and Winkler, new section
Plate 68, figures 20, 21

Dorsal cup about one-half as high as wide, bowl-shaped, with the greatest diameter near the top of the basal plates. Basal and anal plates, the radianal especially, very protuberant, radials somewhat tumid. Basals and radianal with strong ridgelike markings. IBB small, fused into a pentagonal disk, the corners of which protrude beyond the column. BB hexagonal, except the posterior and right posterolateral which are heptagonal, about as high as wide, with very little of the plates involved in the basal invagination, and forming more than two-thirds of the dorsal cup. The tumidity makes them appear almost round. RR pentagonal, about one-half as high as wide, with the greatest extent along the superior edge. Edges of the radials slightly deflected outward where they join the protuberant basals. RA pentagonal, about seven-eighths as wide as long, nearly as large as the radials, very protuberant, and covered with radiating reticulae. Anal *x* hexagonal, nearly as large as the radianal, moderately protuberant, smooth, and almost entirely in the cup. The rt plate is missing from the holotype. It was nearly as large as anal *x*, probably hexagonal, and at least one-half in the cup.

This form is characterized by the very large, protuberant basals with their radiating markings and the character of the anal plates. Its resemblances to *Phanocrinus supratumulosus* and *Ageneracrinus tumulosus* were discussed in the description of *P. supratumulosus*.

*Type.*—Holotype is from the Chester series of Randolph County, Illinois, and is no. 39346 in the Gurley collection at the University of Chicago.

### REFERENCES


BATHER, F. A., *1900*, Echinoderma: in Lankester, *Treatise on Zoology*, pt. 3.

HALL, JAMES, *1858*, Paleontology of Iowa: *Iowa Geol. Survey*, vol. 1, pt. 2, pp. 1–724.

KEYES, C. R., *1894 Missouri Geol. Survey*, vol. 4, pt. 1, pp. 1–239.

KIRK, EDWIN, *1937*, *Eupachycrinus* and related Carboniferous crinoid genera: *Jour. Paleontology*, vol. 11, no. 7, pp. 598–607, pl. 84.

LYON, S. S., *1857*, Paleontologic report: *Kentucky Geol. Survey, Rept.* 3, pp. 465–498, pls. 1–5.

MEEK, F. B., and WORTHEN, A. H., *1865*, Descriptions of new Crinoidea, etc., from the Carboniferous rocks of Illinois and some of the adjoining States: *Acad. Nat. Sci. Philadelphia, Proc.*, ser. 1, vol. 17 (ser. 2, vol. 9), pp. 155–166.

——, *1866*, Descriptions of Invertebrates from the Carboniferous system: *Illinois Geol. Survey*, vol. 2, sec. 2, pp. 143–411, pls. 14–32.

——, *1870*, Descriptions of new species and genera of fossils from the Paleozoic rocks of the Western States: *Acad. Nat. Sci. Philadelphia, Proc.*, pp. 22–56.

——, *1873*, Descriptions of Invertebrates from the Carboniferous system: *Illinois Geol. Survey*, vol. 5, pt. 2, pp. 323–619, pls. 1–32.

——, *1875*, Descriptions of Invertebrates: idem, sec. 2, pp. 489–532, pls. 23–33.

MILLER, S. A., *1879*, Remarks upon the Kaskaskia group, and descriptions of new species of fossils from Pulaski County, Kentucky: *Cincinnati Soc. Nat. History, Jour.*, vol. 2, pp. 31–42, pl. 8.

——, *1892*, Paleontology: *Indiana Geol. Survey, Rept.* 17, pp. 611–705, pl. 1–20.

——, *1894*, New genera and species of Echinodermata: *Illinois State Mus. Nat. History, Bull.* 5.

——, *1895*, Description of new species of Palaeozoic Echinodermata: *Illinois State Mus. Nat. History, Bull.* 6.

MILLER, S. A., and GURLEY, WM. F. E., *1889*, Description of some new genera and species of Echinodermata from the Coal Measures and Subcarboniferous rocks of Indiana, Missouri, and Iowa: *Indiana Geol. Survey, Rept.* 16, pp. 327–373, pl. 1–10.

——, *1893*, Description of some new species of invertebrates from the Palaeozoic rocks of Illinois and adjacent States: *Illinois State Mus. Nat. History, Bull.* 3.

MOORE, R. C., *1938*, The use of fragmentary Crinoidae remains in stratigraphic paleontology: *Dennison Univ., Sci. Lab., Bull.*, vol. 33, pp. 165–251.

SHUMARD, B. F., *1866*, A catalogue of the Paleozoic fossils of North America (Echinodermata): *St. Louis Acad. Sci., Trans.*, vol. 2.

SPRINGER, FRANK, *1911*, Some new American fossil crinoids: *Harvard Coll. Mus. Comp. Zoology, Mem.*, vol. 25, no. 3.

——, *1926*, Unusual forms of fossil crinoids: *U. S. Nat. Mus. Proc.*, vol. 67, art. 9.

STRIMPLE, H. L., *1938*, *A group of Crinoids from the Pennsylvanian of Northeastern Oklahoma.*

SUTTON, A. H., and HAGAN, W. W., *1939*, Inadunate crinoids of the Mississippian, *Zeacrinus: Jour. Paleontology*, vol. 13, no. 1, pp. 82–96, pl. 15.

TIEN, C. C., *1926*, Crinoids from the Yaiyuan series of North China: *Palaeontologia Sinica*, ser. B, vol. 5, fasc. 1.

TRAUTSCHOLD, *1867*, *Crin jüng. Bergkalk bei Moskau*.

WACHSMUTH, CHARLES, and SPRINGER, FRANK, *1879–1886*, Revision of the Paleocrinoidea: *Acad. Nat. Sci. Philadelphia, Proc. 1879*, pp. 226–378; *1881*, pp. 177–414; *1885*, pp. 225–364; *1886*, pp. 64–226.

——, *1890*, New species of crinoids and blastoids from the Kinderhook group of the Lower Carboniferous rocks at LeGrand, Iowa; and a new genus from the Niagara group of western Tennessee: *Illinois Geol. Survey*, vol. 8, pt. 2, sec. 2, pp. 155–208, pls. 9–28.

WELLER, STUART, *1898*, A bibliographic index of North American Carboniferous invertebrates: *U. S. Geol. Survey, Bull.* 153.

WHITE, C. A., and ST. JOHN, O. H., *1867*, Descriptions of new Subcarboniferous and Coal Measure fossils collected upon the geological survey of Iowa; together with a notice of new generic characters observed in two species of brachiopods: *Chicago Acad. Sci., Trans.*, vol. 1, pp. 115–129, 10 figs.

WOOD, ELVIRA, *1909*, A critical summary of Trost's unpublished manuscript on the crinoids of Tennessee: *U. S. Nat. Mus., Bull.* 64.

WORTHEN, A. H., *1882*, *Illinois State Mus. Nat. History, Bull.* 1.

——, *1890*, Description of fossil invertebrates: *Illinois Geol. Survey*, vol. 8, pt. 2, sec. 1, pp. 69–154, pls. 9–28.

WORTHEN, A. H., and MILLER, S. A., *1883*, Description of Fossil Invertebrates: *Illinois Geol. Survey*, vol. 7, sec. 2, pp. 269–364, pls. 27–31.

WRIGHT, JAMES, *1925*, Notes on the occurrence of crinoids in the Carboniferous limestones in Scotland: *Edinburgh Geol. Soc., Trans.*, vol. 11, pl. 3.

——, *1926*, Notes on the anal plates of *Eupachycrinus calyx* and *Zeacrinus koninckı: Geol. Mag.*, vol. 63, no. 742.

YANDELL, L. P., and SHUMARD, B. F., *1847*, *Contributions to the Geology of Kentucky*.

MANUSCRIPT RECEIVED BY THE EDITOR FEBRUARY 2, 1940.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 6, PP. 568–571, PL. 69, 2 TEXT FIGS., NOVEMBER, 1940

# NEW GENUS OF FORAMINIFERA FROM THE LATER TERTIARY OF CALIFORNIA

M. L. NATLAND
Richfield Oil Corperation, Los Angeles, Calif.

ABSTRACT—Two species of the new genus *Cassidulinella* are figured and described together with figures showing the known geographic and stratigraphic occurrences of the species in the Miocene and Pliocene of Southern California. The new species *Cassidulinella renulinaformis* has been found at a number of widespread localities and makes a good zone for correlation. *Cassidulinella pliocenica* Natland, n. sp. has been found in the Upper Pliocene of the Ventura and Los Angeles Basins.

FOR SEVERAL years micropaleontologists working in Southern California have been calling a crushed impression of a certain foraminifer by the generic name "*Renulina*." Recently, well-preserved specimens of this form were found, and a study of these specimens shows that the early chambers are coiled and biserial, similar to those of *Cassidulina*, and that the later chambers are also biserial but rapidly increase in length, so that in many cases they nearly encircle the entire test. The fact that the test is biserial excludes it from *Renulina* and necessitates the erection of the new genus, *Cassidulinella*.

*Cassidulinella renulinaformis* Natland, n. sp. has been found in almost all the Upper Miocene sections studied in the coastal region of Southern California. As yet it has not been found by the writer in the Upper Miocene of the San Joaquin Valley. However, additional study of the part of the sec-

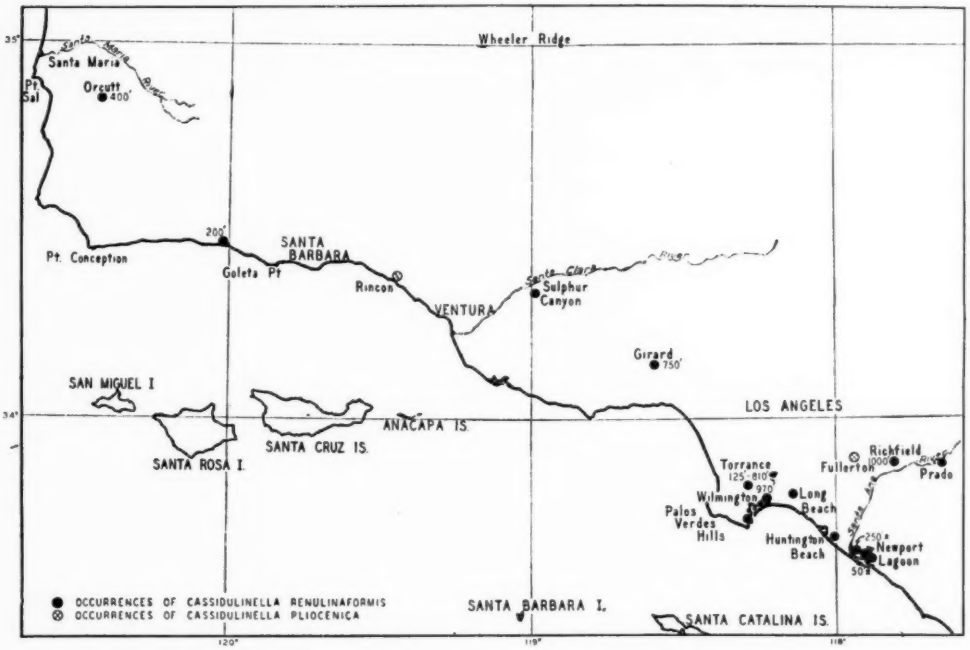



FIG. 1.—Location of known occurrences of *Cassidulinella*. The thickness of the *C. renulinaformis* zone is given where known.

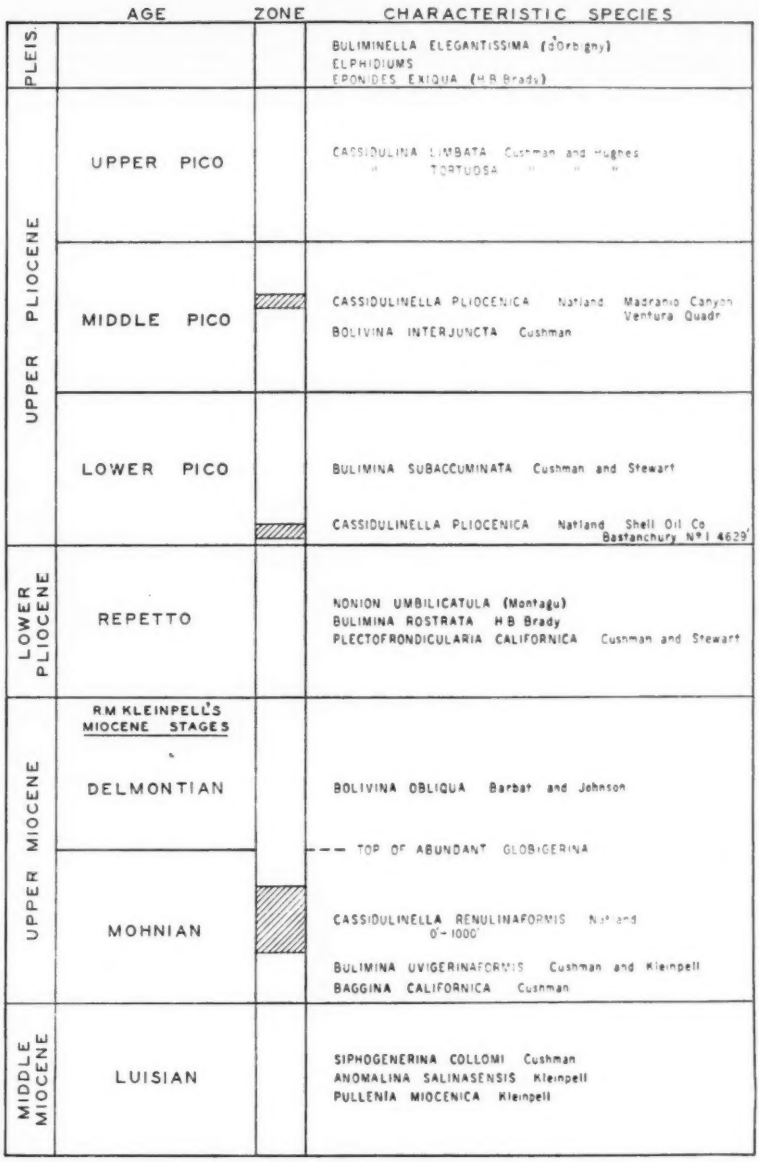



FIG. 2.—Chart showing relative stratigraphic position of occurrences of *Cassidulinella pliocenica* Natland and *Cassidulinella renulinaformis* Natland.

tion that should contain this species may reveal its presence in that area.

Figure 1 shows the location of the known occurrences of *Cassidulinella renulin formis* and *Cassidulinella pliocenica*, n. sp. The stratigraphic thickness of the *C. renulinaformis* zone is indicated where known. *C. pliocenica* has been found only at two localities and in different parts of the Upper Pliocene section in both areas. At both localities this species was preserved only in the form of pyrite casts. *C. renulinaformis*

is usually too badly crushed to wash out. However, on surfaces of cores and of outcrop samples the crushed patterns are so distinctive in most cases that it is not difficult to recognize the species. A typical pattern on a core is shown on plate 69, figure 7.

The approximate stratigraphic positions of the two new species described here are shown on figure 2. In the Ventura Basin, *C. pliocenica* was found in an outcrop section in Madranio Canyon, near Rincon Point. This section was collected from beds of Middle Pico age by Mason Hill. In the Los Angeles Basin, *C. pliocenica* was found in the Shell Oil Company Bastanchury no. 1 well in beds near the base of the Lower Pico at a depth of 4629 feet. This is the only occurrence of this species known to the writer in the Los Angeles Basin.

The top of the *C. renulinaformis* zone occurs below the top of Kleinpell's (1938, p. 127) Mohnian stage, which is probably of Upper Miocene age. The base of the *C. renulinaformis* usually terminates near the top of the *Bulimina uvigerinaformis* zone. However, the interval between these two zones varies considerably, and in some areas *C. renulinaformis* is found extending down into the *Bulimina uvigerinaformis* zone.

The writer acknowledges the assistance of Dr. Joseph A. Cushman, who checked the validity of the new names listed here. He is also indebted to Mr. W. Thomas Rothwell of the Richfield Oil Corporation for assistance in studying the Miocene sections. The author wishes to thank Dr. H. W. Hoots of the Richfield Oil Corporation for permission to publish these data.

The accompanying figures are photographs of the type specimens. The type specimens are deposited in the U. S. National Museum collection at Washington, D. C. A duplicate set is deposited at the Cushman Laboratory for Foraminiferal Research at Sharon, Mass.

## DESCRIPTION OF SPECIES

Family CASSIDULINIDAE
Subfamily CASSIDULININAE
Genus CASSIDULINELLA Natland, n. gen.

Genotype, *Cassidulinella pliocenica* Natland, n. sp.

### CASSIDULINELLA PLIOCENICA Natland, n. sp.

Plate 69, figures 5, 6a–c

Test flat with parallel sides, nearly oval in side view; chambers coiled, biserial, *Cassidulina*-like; later ones rapidly increasing in length, so that they extend more than half-way around the test; walls thin, finely perforate; sutures distinct, depressed; aperture extending full length near the periphery between the last two chambers. Length, 0.73 mm.; breadth, 0.64 mm.; thickness, 0.20 mm.

Types (U. S. Nat. Mus. 546447). From Shell Oil Company Bastanchury no. 1 well, near northwest corner of Section 28, T. 3 S., R. 10 W., Corona quadrangle. This species was found to be abundant at a depth of 4629 feet in beds belonging to the Lower Pico formation of Upper Pliocene age. It has also been found in outcrops exposed in Madranio Canyon, near Rincon Point, Calif. The location is more accurately described as follows: 1200 feet E. and 40 feet N. of the southwest corner of Section 9, T. 3 N., R. 24 W., S.B.B.M. These outcrops occur in the Middle Pico formation of Upper Pliocene age.

---

EXPLANATION OF PLATE 69

FIGS. *1–4, 7—Cassidulinella renulinaformis* Natland, n. sp. U. S. Nat. Mus. 546,548. (p. 571)

*1*, Holotype, ×46. a, side view; b, apertural view; c, opposite side. From a well in the Orcutt area.

*2*, Paratype, ×50. Side view; section showing chamber arrangement.

*3*, Paratype, ×35. Side view; section showing chamber arrangement.

*4*, Holotype, ×46. Side view, crushed form. From El Capitan Point.

*7*, Paratype, ×27. Typical impression in core material from Los Angeles Basin, California; specimen from General Petroleum Corporation Terminal no. 1 well; depth, 5000'; Wilmington Oil Field, California.

*5, 6—Cassidulinella pliocenica* Natland, n. sp. U. S. Nat. Mus. Coll. no. 546,447. (p. 570)

*5*, Side view, young stage, ×53.

*6*, Holotype, ×48. a, Side view; b, apertural view; c, opposite side.

Natland, Tertiary Foraminifera

UNIV. OF MICH.

CASSIDULINELLA RENULINAFORMIS
Natland, n. sp.

Plate 69, figures 1a–c, 2–4, 7

Test flat with nearly parallel sides; nearly oval in side view; chambers biserial, coiled, *Cassidulina*-like; later chambers rapidly increasing in length until they completely surround the entire test; walls calcareous, smooth, finely perforate; sutures distinct, slightly depressed; aperture narrow, opening extending full length near the periphery between the last two chambers. Length 1.17 mm.; breadth, 0.94 mm.; thickness, 0.18 mm.

Holotype (U. S. Nat. Mus. 546448). From a depth of 2165′ in the Union Oil Company's Newlove no. 51, located in Section 25, T. 9 N., R. 34 W., in the Orcutt field, Santa Barbara County, California. Impressions of this species are abundant in core surfaces taken from this well. In addition to these impressions a few calcite-filled specimens were recovered intact; these furnished the author with the first details of the structure of the genus.

REFERENCE

KLEINPELL, R. M., *1938*, Miocene stratigraphy of California: *Am. Assoc. Petroleum Geologists*, Spec. Pub., p. 127.

MANUSCRIPT RECEIVED BY THE EDITOR DECEMBER 6, 1939.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 6, PP. 572–583, 3 TEXT FIGS., NOVEMBER, 1940

# EARLY GROWTH STAGES OF CARBONIFEROUS MICROCRINOIDS AND BLASTOIDS

RAYMOND C. MOORE
University of Kansas, Lawrence, Kansas

ABSTRACT—Immature microcrinoids representing several Carboniferous species begin as armless calices and gradually develop arms on the different radials. The order of development of the arms is generally constant. A remarkable series of growth stages of a new species of *Allocatillocrinus*, from lower Pennsylvanian rocks of Oklahoma, similarly shows the nature of arm development and indicates that this genus is derived from *Allagecrinus*. Comparison of the immature crinoids is made with larval blastoids described by Croneis and Geis, and orientation of the calices of the very young blastoids is discussed.

## INTRODUCTION

MUCH importance is rightly attached to ontogenetic studies in paleontology. Determination of growth stages of fossil organisms helps to safeguard against errors such as the setting up of invalid species based on immature individuals, and it promotes sound taxonomy by contributing evidence for proper definition of genera, families, and larger classificatory divisions. Far too little attention is given by most workers on invertebrate fossils to this type of study. The small number of classes and orders of invertebrates that have provided the materials for published investigations is also noteworthy.

Studies of the growth stages of fossil echinoderms are among the less common and more difficult of ontogenetic researches. This is due, in the first place, to the manner in which skeletal elements of the young crinoid, cystoid, or other echinoderm class is introduced and the way in which it is expanded in various directions, mostly without leaving trace of the mode of introduction or steps in the expansion. Accordingly, it is necessary to find different individuals that severally represent the successive stages of development, and all of these growth stages must be recognizable as belonging properly to the species under investigation. A second difficulty springs from the first, namely, that fossils representing a reasonably complete growth series for most species of echinoderms are hard to obtain. Fragmentary remains of echinoderms are extremely common in many strata, but complete specimens, either mature or immature, are scarce. The few localities that have yielded considerable numbers of crinoids have gained fame because they are exceptions to so general a rule. Yet the collections from such places as Burlington, Ia., and Crawfordsville, Ind., have supplied surprisingly little material that has been used in ontogenetic studies. Blastoids occur in great numbers in some Mississippian beds, and complete specimens of echinoids are abundant in some Mesozoic and younger deposits, but very few attempts have been made to determine the developmental stages of these echinoderms leading up to adult forms. A third point is the structural complexity of many echinoderms, and the fact that important parts may be lacking in the obtainable fossil remains. The dorsal cup of a crinoid is only a small part of the entire organism, but it is rarely that dorsal cups representing a series of growth stages can be found. The ontogeny of crinoid species, and of most other echinoderms, must be determined, if at all, on fragmentary material.

*Scope of this paper.*—The foregoing remarks provide explanation, if such is needed, for publication of somewhat incomplete and disconnected observations on growth stages of fossil echinoderms. Attention is directed in this paper to (1) the development of arms on the cups of some Carboniferous microcrinoids, (2) interpretation of the taxonomic significance of a remarkable growth series of a species of *Allocatillocrinus*, (3) comparison between

some of the microcrinoids and larval blastoids, and (4) orientation of the larval blastoids described recently by Croneis and Geis (1940).

### DEVELOPMENT OF ARMS OF MICROCRINOIDS

*Growth stages of Allagecrinus.*—The genus *Allagecrinus* was established by Carpenter and Etheridge (1881) on the basis of three somewhat asymmetrical dorsal cups measuring about 3 mm. in height and width, and a dozen or more very small symmetrical calices, about 1 mm. in height and 0.7 mm. in width. All the specimens obtained from Lower Carboniferous beds in Scotland were regarded as belonging to a single species, *A. austinii*, which was designated as the type of the new genus. The large cups seemed to represent adults and the small ones immature specimens. Wanner (1929, p. 11) and Wright (1932, p. 342) concluded that the immature specimens, as interpreted by Carpenter and Etheridge, are really adults belonging to species of *Allagecrinus* distinct from *A. austinii*. J. M. Weller (1930, p. 8) agreed that the microscopic Scottish crinoids were specifically distinct from *A. austinii*, but he concluded also that they belonged to a new genus that he proposed, called *Callimorphocrinus*. Weller's interpretation was accepted by Wright in 1933 (p. 206), and the genus *Callimorphocrinus* has come to be recognized generally (Peck, 1936; Bassler, 1938; Wright, 1939; Moore and Plummer, 1940; Moore, 1940). This leaves open the question whether immature examples of *Allagecrinus* may occur in the Scottish beds containing *Callimorphocrinus* associated with adult specimens of *Allagecrinus*, and whether growth stages of *Allagecrinus* may be found in other places.

Work by Wright (1932, 1933, 1939) has resulted in the finding of about 80 specimens of *Allagecrinus austinii*, two dozen or more cups that are assigned to species called *A. garpelensis* and *A. biplex*, and about 1000 minute calices that are classed as belonging to *Callimorphocrinus*. Immature growth stages leading up to *A. austinii*, and belonging in part to the other species of *Allagecrinus* mentioned, are distinguished mainly from the specimens of *Callimorphocrinus* by means of the differentiation of the right posterior radial (rpR) in the young *Allagecrinus* and lack of such differentiation in *Callimorphocrinus*. Six minute calices, the smallest about 0.7 mm. in height, are regarded by Wright (1932, p. 345) as representing a very early stage of *A. austinii* that is characterized by absence of arm facets on all radials; the calices are similar in shape and surface markings to *A. austinii* and are unlike associated armless young *Callimorphocrinus* individuals, which differ in shape and in smaller size (0.4 to 0.5 mm. height). Two specimens having three facets are described, but the radials bearing them are not identified. Slightly more advanced growth stages show three arm facets (on the rpR, laR, and raR). Specimens that carry four facets indicate that the lpR develops an arm next, and finally in the five-armed stage the aR becomes a facet-bearing radial. Maturity cannot be regarded as attained in *Allagecrinus* at the stage where five facets make appearance, for a characteristic feature of the genus, as illustrated by the genotype species, is the presence of axillary radials. A list by Wright (1933, p. 202) of 79 specimens of *A. austinii* that bear five or more facets shows the following distribution: five facets, nine specimens; six facets, five specimens; seven facets, 24 specimens; eight facets, 26 specimens; nine facets, 13 specimens; 10 facets, two specimens. This indicates that mature status is attained at the seven-arm stage, and that two or even three additional arms may develop subsequently. Weller's (1930, p. 13) genus *Hybochilocrinus* corresponds to *Allagecrinus* in asymmetry of form and in having an anal plate attached to the left shoulder of the rpR, but it is less advanced in that mature calices bear only five arms. The five-armed immature stage of *Allagecrinus* may thus be construed as representing the *Hybochilocrinus* stage. The oldest known examples of *Allagecrinus*, as this genus is now interpreted, come from the upper part of the Lower Carboniferous series, whereas *Hybochilocrinus* is found in lower Mississippian (Chouteau limestone and Louisiana limestone) rocks of Missouri. Branson (1938, p. 5) regards the Louisiana limestone as Upper Devonian.

Growth stages are shown of *Allagecrinus pecki*, n. sp., Moore, 1940 described else-

where, that occurs in topmost beds of the Cherokee shale in central Missouri, near Columbia. A lot of 13 specimens that was collected by Raymond E. Peck of the University of Missouri contains individuals that range in longest dimension from about 1 mm. to 3.5 mm. That the specimens belong to a single species is indicated by grada-

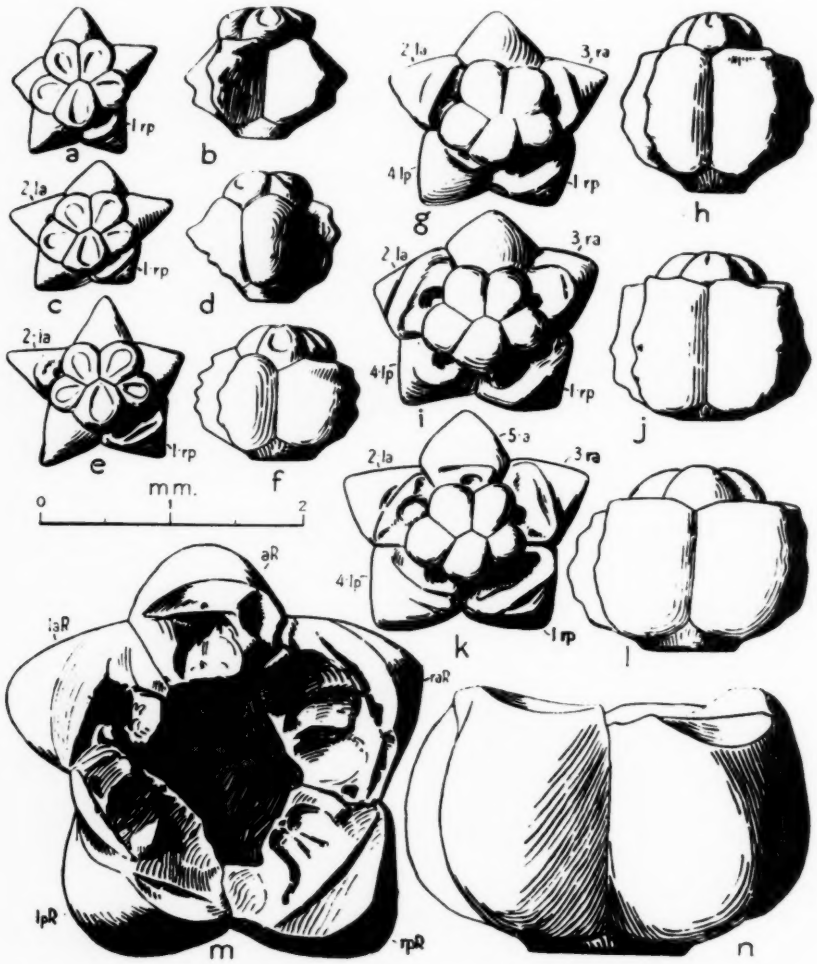



FIG. 1.—Growth stages of *Allagecrinus pecki*, n. sp., from the uppermost Cherokee shale in Boone County, central Missouri, showing the changes in outline of the calyx and in number of arm facets. *a*, *b*, A very immature individual, which has only one arm facet, located on the rpR; views from the ventral and rp-ra interradius sides. *c*, *d*, A specimen having a well-formed facet on the rpR and an incipient one on the laR; ventral and lpR views. *e*, *f*, A slightly larger calyx having two well-developed facets; ventral and posterior views. *g*, *h*, A calyx that has passed the three-arm stage and shows an incipient facet on a fourth radial, lpR; ventral and posterior views. *i*, *j*, Specimen showing the typical four-arm development; ventral and posterior views. *k*, *l*, A facet has appeared on the aR in this specimen, making the five-arm stage; ventral and posterior view. *m*, *n*, A fully grown dorsal cup, showing multifaceted radials (lpR, aR, raR); ventral and posterior views.

tion of characters between the two extremes, no abrupt change being seen at any point. The smallest calyx (fig. 1a, b) bears a well developed facet on the rpR; a slightly larger one (fig. 1e, f) has two facets that are located respectively on the rpR and laR; a still larger example (fig. 1g, h) shows three well-formed facets, on the rpR, laR, and raR, and an incipient fourth facet, on the lpR; in another specimen (fig. 1i, j) four facets are clearly defined and it is evident that all radials except the aR are arm-bearing; a later stage is represented by individuals (fig. 1k, l) that have five distinct facets. The largest specimens have multifaceted radials in two or more of the rays. The dorsal cup illustrated (fig. 1m, n) carries two facets on the lpR, one facet and an incipient additional facet on the aR, and two facets on the raR; the other radials each bear a single facet. Another specimen shows the same distribution of facets except that two clearly defined facets appear on the aR. The oral circlet, which is retained during the immature stages, is not observed in mature specimens. This seemingly means that the union between the orals and radials became weakened as the cup approached maximum size so that the orals, like the arms, became detached before the burial of the cup in the Cherokee sediments.

*Hybochilocrinus and Callimorphocrinus.*—Both *Hybochilocrinus* and *Callimorphocrinus* have five arm facets at maturity, although Wright (1939, p. 52) notes that exceptionally there are specimens of *C. elongatus* having as many as eight arm facets. The occurrence of more than five facets is clearly a departure from the norm for these genera, indicating an evolutionary trend of the sort that seems to have produced *Allagecrinus* out of *Hybochilocrinus* or an ancestor very similar to this genus.

Growth stages of *Hybochilocrinus* have been recorded only by Peck (1935, 1936). He describes earliest observed forms of *H. americanus* (Rowley), a species that occurs abundantly in the Louisiana limestone, as nearly symmetrical armless calices about 0.5 mm. in height; the laR is distinguishable in these very young specimens by reason of its slightly smaller width. As size increases, facets are seen to appear on some of the radials, first on the rpR and laR, nearly simultaneously, and then on the raR and lpR. Maturity is reached when all five of the radials become arm-bearing, the height of full-grown individuals ranging from about 1 to 1.3 mm. The same steps are observed (Peck, 1936, p. 284) in the development of *H. rowleyi* (Peck), which occurs in the Chouteau limestone. Youngest specimens are armless and nearly symmetrical. Facets make appearance in the order reported for *H. americanus* and the cup becomes increasingly asymmetrical as the lpR and rpR grow wider than the other radials.

Immature specimens of *Callimorphocrinus* have been studied extensively by Wright (1932), who finds that the Scottish species, *C. scoticus* (Wright) and *C. elongatus* (Wright), begin as very small armless calices and pass through successive stages having one to five facets at the summits of the radials. The order of appearance of the facets seems to follow no definite rule, however. This is strange in view of evidence from the study of other species, and because the method of Wright's determination of the orientation of his specimens is not given, question remains as to the correctness of his observations. Seemingly the most constant and reliable basis for determining orientation of microcrinoids is found in characters of the oral circlet, as pointed out by Kirk (1937, p. 111). The posterior oral is almost invariably a little wider than the others, different from them in shape, and identifiable by the nature of its contacts with other plates of the circlet; in some specimens it bears a tubercle or hydropore.

Peck (1936, p. 288) has described growth stages belonging to two lower Mississippian species of *Callimorphocrinus*, *C. pristinus* Peck and *C. puteatus* Peck, both occurring in the Fern Glen limestone of Missouri. Very early stages are armless. Facets appear first on the rpR and laR, later on the raR and lpR, and last of all on the aR. The form of the calyx remains symmetrical, and no anal series is developed in this genus.

Weller (1930, p. 22) notes a single case of a Pennsylvanian specimen of *Callimorphocrinus* having less than five arm facets. This is the holotype of *C. infacetus* Weller, from beds of Des Moines age in Indiana, and it is indicated by the specific name, as well as by Weller's discussion, that the

absence of an arm facet on one of the radials may be a character of taxonomic value. Clearly it is not. The type of *C. infacetus* is an immature specimen that lacks a facet on the aR.

A few specimens of *Callimorphocrinus* from Pennsylvanian rocks of Missouri and Kansas, that I have had opportunity to study, include immature calices, but connected series of growth stages are not available. None of the observed immature calices fails to fit somewhere in the facetal sequence 1-rpR, 2-laR, 3-raR, 4-lpR, 5-aR.

The observations on the order of appearance of the arms in immature microcrinoids is summarized in the following table, in which the bracketed groups of radials show virtually simultaneous appearance of arm facets or follow an unknown order among themselves. The arrangement of the radials within the bracketed groups, as given in the table, is arbitrary.

ORDER OF DEVELOPMENT OF FACETS ON RADIAL PLATES OF MICROCRINOIDS

| Species | First | Second | Third | Fourth | Fifth |
|---|---|---|---|---|---|
| *Allagecrinus pecki*, n. sp. | rpR | laR | raR | lpR | aR |
| *Allagecrinus austinii*[1] | rpR | laR | raR | lpR | aR |
| *Hybochilocrinus americanus*[2] | rpR | laR | raR | lpR | aR |
| *Hybochilocrinus rowleyi*[3] | rpR | laR | raR | lpR | aR |
| *Trophocrinus corpulentus*[4] | rpR | laR | lpR | — | — |
| *Callimorphocrinus pristinus*[5] | rpR | laR | raR | lpR | aR |
| *Callimorphocrinus puteatus*[5] | rpR | laR | raR | lpR | aR |
| *Callimorphocrinus scoticus*[6] | | | Variable | | |
| *Callimorphocrinus elongatus*[6] | | | Variable | | |

[1] Wright (1933, p. 203).
[2] Peck (1935, p. 768).
[3] Peck (1936, p. 285).
[4] Peck (1936, p. 287).
[5] Peck (1936, p. 287).
[6] Wright (1932, p. 357).

## ONTOGENY OF A SPECIES OF ALLOCATILLOCRINUS

The genus *Allocatillocrinus* was introduced by Wanner (1937, p. 111) to include somewhat strongly asymmetrical dorsal cups having three multifaceted radials and two single-faceted radials. The multifaceted plates, which are much larger than the others, each bear four to 18 arms, and as judged by the narrow width of the facets, the arms attached to these plates are far more delicate and slender than the robust arms borne by the two small radials. The genotype of *Allocatillocrinus* is *Allagecrinus carpenteri* Wachsmuth (1882) from Chester beds of Illinois, Indiana, and Alabama. Other described species include *A. scoticus* (Wright, 1933) and *A. morrowensis* (Strimple, 1940). Specimens belonging to the genus are rare, about 20 individuals belonging to the genotype species and two each for the other two species being recorded. Special interest is attached, therefore, to the discovery of more than 30 specimens that show essentially complete growth series from early immature forms to fully developed adults. The specimens (*A. rotundus*, n. sp.) occur in beds of Morrow age in northeastern Oklahoma, coming from two localities, but most of them from a single small outcrop of calcareous shale about 2 feet thick (Moore, 1940).

Attention is directed here to the steady increase in the number of arm facets of the three large radials as growth proceeds. The small immature cups are strongly lobate in outline and are ornamented by tubercles;

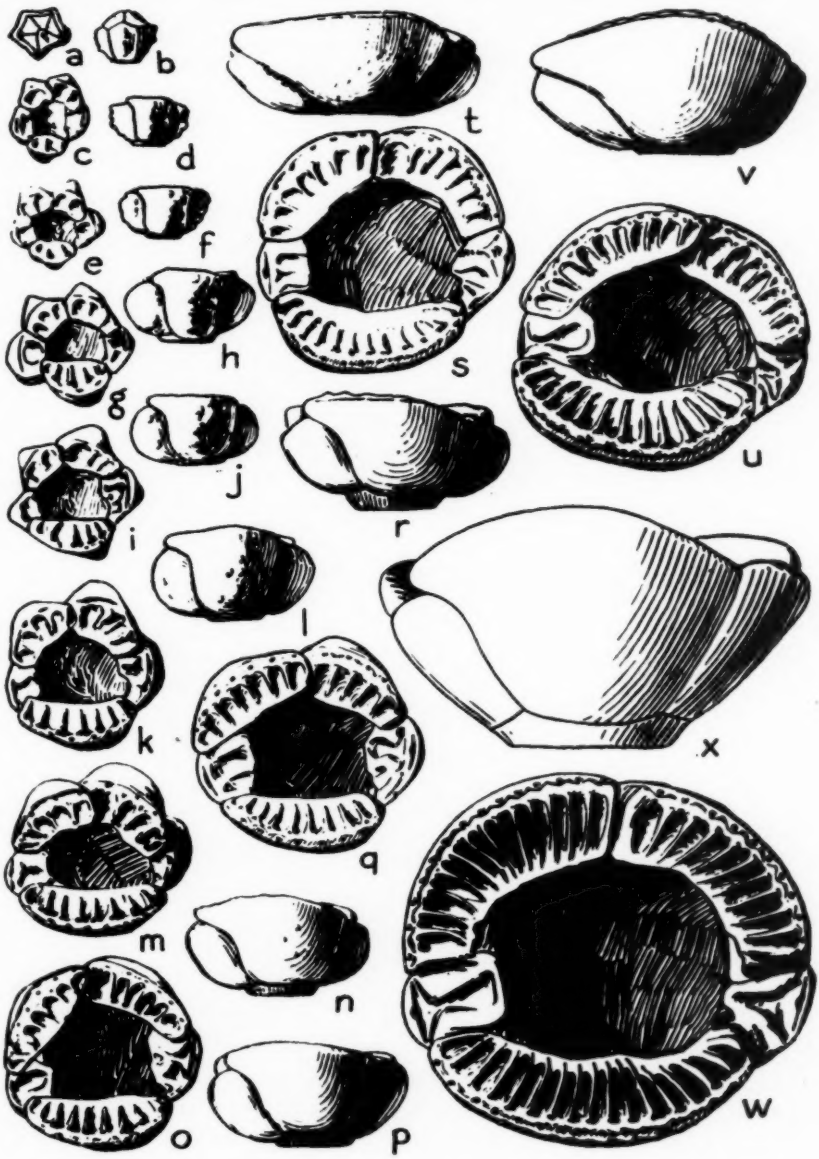



FIG. 2.—A series of growth stages belonging to *Allocatillo crinus rotundus*, n. sp., from Morrow beds of northeastern Oklahoma. All of the figures are drawn to the same scale, and two views of each specimen are given, a ventral view oriented so that the lpR is at the bottom and laR at the left, and a side view in which the lpR is toward the observer. *a*, *b*, A two-faceted calyx that retains the oral circlet, believed to belong in this series because of surface characters and other evidence, but not certainly determinable as belonging. *c*, *d*; *e*, *f*; *g*, *h*; *i*, *j*, Specimens that have all typical characters of *Allagecrinus* and if found alone would doubtless be so identified. *k*, *l*; *m*, *n*; *o*, *p*; *q*, *r*; *s*, *t*; *u*, *v*; *w*, *x*, Specimens that show increasingly well marked characters of *Allocatillocrinus*, the largest three being classifiable as adults. (All figures ×5.)

intermediate stages are less lobate and less decorated; and the late stages retain almost no trace of lobation or decoration. These developments are illustrated in figure 2. Phylogenetic significance seems to attach to the observation that some of the early growth stages (fig. 2c–i), up to a limiting greatest width of about 4 mm., are indistinguishable from *Allagecrinus*. Transition to *Allocatillocrinus* is recognized in the continued multiplication of arm facets on the large radials. After passing the *Allagecrinus* stage, immaturity persists for a time in which size is almost doubled, but there is no definite indication of the line marking attainment of maturity. The maximum observed width of a cup belonging to this species is 11.7 mm. and this large specimen has the largest number of arms, which is 42.

Three specimens of *Hybochilocrinus*-like or *Callimorphocrinus*-like appearance that are found associated with the dorsal cups of *Allocatilocrinus* described, seem to belong in the growth series of this species, for they correspond to the smallest multifaceted cups in decoration. The form of the three specimens, which measures 1.2 to 1.5 mm. in width, is more symmetrical and slightly more pentagonal than the next larger cups. The specimen shown in figure 2a, b bears an arm facet on the rpR and another on the laR, the other radials being armless. Obviously, a considerable gap exists between the minute calices having a single arm facet on some of the radials and possessing the oral circlet, and the smallest multifaceted cups. Comparison with the growth stages of *Allagecrinus* indicates probability that the same succession holds for *Allocatillocrinus*.

The evidence from the ontogeny here presented seems clearly to indicate that *Allocatillocrinus* is derived from *Allagecrinus*, or from an ancestor that differs inappreciably from *Allagecrinus*. *Allocatillocrinus* is currently classed with *Catillocrinus* and several related genera in the family Catillocrinidae, of the suborder Fistulata, whereas *Allagecrinus* is the type genus of the family Allagecrinidae, assigned to the suborder Larviformia. Present classification is indeed faulty if the significance of the growth series is what it seems to be.

## COMPARISON OF GROWTH STAGES OF MICROCRINOIDS AND LARVAL BLASTOIDS

The very interesting study of growth stages of larval blastoids recently published by Croneis and Geis (1940) brings knowledge in a field that has been a complete blank. The paper on blastoids is avowedly preliminary in nature, being the first of proposed contributions by these authors, and partly because of this, rather than in spite of it, some features of their study are discussed here. The microscopic young blastoids come from lower Chester beds of southern Illinois, and they are identified as representing two species, *Mesoblastus glaber* (Meek and Worthen) and *Pentremites princetonensis* Ulrich. Specimens that are less than 0.5 mm. in height are reported to outnumber larger forms in the ratio of about 50 to 1.

The numerous specimens that are classed by Croneis and Geis as belonging to larval stages are smaller in average size than the youngest recorded microcrinoids assigned to genera such as *Callimorphocrinus* and *Hybochilocrinus*. Armless calices of the microcrinoids mentioned, about 0.5 mm. in height, correspond in size to the "fourth stage" of the larval blastoids, which are more than twice as large as some of the earlier forms. Notice should be taken of the fact that the "fourth stage" larval blastoid has dimensions of about one-twentieth of adult measurements, whereas the most immature known microcrinoid specimens are one-third to one-half as large as adult forms. Nevertheless, the form and structure of "fourth stage" or even "third stage" larval blastoids and of the minute armless crinoid calices are strikingly similar. In each group, the calyx comprises 13 plates that include three basals (fused in many of the microcrinoids), five radials, and a prominent circlet of five orals. Croneis and Geis designate the "orals" of larval blastoids as distals, because these plates seem to disappear during a so-called metamorphosis and, thus, these authors do not believe that the "distals" are the deltoids or orals (Bather, 1900, p. 97; Springer, 1913, p. 162) of adult blastoids. Proof of the interpretation of "distals" is not adequately presented in the preliminary paper by Croneis and Geis,

and it may be hoped, if not assumed, that this will receive more detailed treatment in a later publication.

Special interest attaches to the observation that "semilunar depressions or pits with slightly elevated margins" (Croneis and Geis, 1940, p. 349) occur at the summit of some radials on the calices of immature blastoids. These facets lie at the base of food grooves between the "distals" and are interpreted by Croneis and Geis as points of arm attachment. This affords further ground for comparison of the young blastoids and crinoids. The presence of an arm or "brachiole" rising from the summit of a radial plate of the larval blastoid is seemingly not to be compared with the development of pinnules along the margins of ambulacral areas at later growth stages. The nature of the indentations of radials as described in the very early stages of the blastoids suggests the form of arm facets of some crinoids and cystoids. Such facets appear at the proximal extremities of the ambulacra in adult specimens of *Stephanocrinus* (Ordovician and Silurian), which Wanner (1924, p. 17) has shown is properly classified as a blastoid rather than crinoid. The blastoids were derived evidently from an echinoderm stock that was already specialized in having the basal circlet reduced to three plates, for this character is seen in the earliest blastoids as well as in the latest, and according to inference from characters of larval blastoids, the ancestral forms were provided with crinoid-like arms. However this may be, it is interesting to notice that the arm structures of young blastoids do not appear simultaneously or nearly so, but are found only on certain radials at a given stage of growth. This is true also of microcrinoids. Croneis and Geis (1940, p. 354) indicate that there is a definite order of development of the blastoid arm facets. On one-armed calices, a facet is located on the rpR; two-armed calices have facets on the rpR and laR, and those having three facets show that the third one is introduced on the raR. Four-armed calices are mentioned, but the position of the additional facet is not indicated.

The parallelism in order of arm development in the immature blastoids and in at least some microcrinoids is surprising. It is a feature that attracted my special attention. Examination of the drawings given by Croneis and Geis, however, shows that their designation of the position of the facet-bearing radials, as just reported, is erroneous. Because of incorrect orientation of the anteroposterior axis of the calices (not questioning the identification of this axis), designation of right and left elements is interchanged. The right posterior radial (rpR) of usage by Croneis and Geis must be translated to left posterior radial (lpR), laR to raR, lpR to rpR, and raR to laR. This change causes the presumed similarity in order of arm development among blastoids and microcrinoids to disappear, because the corrected statement of the order for blastoids is: lpR, raR, laR, and later ones not reported. The subject of orientation is not disposed of simply by inverted "left" and "right," however, and it seems desirable to discuss some of the questions that are encountered.

## ORIENTATION OF IMMATURE BLASTOID CALICES

Identification of dorsal and ventral portions of the blastoid calyx offers no difficulty, of course, but determination of anterior and posterior may not always be easy. Once these essential directrices are ascertained, however, a reasonable and natural convention dictates that the calyx shall be oriented in a manner that is familiar to all students of the echinoderms. This orientation and the designation of skeletal elements that is dependent on it are so universally accepted that one must regard the deviation from it by Croneis and Geis as unintentional. Such an interpretation seems unreasonable, especially when account is taken of steps in handling the manuscript, leading to publication, but more unreasonable is the assumption that an intentional change in methods of orienting and designating parts of the blastoid or crinoid calyx was left without specific indication and supporting reasons. Figures 3a and 3b show in somewhat condensed manner the orientation of dorsal cups and designation of radials as given by Croneis and Geis. Figures 3c and 3d make corrections but do not alter identification of the anteroposterior axis.

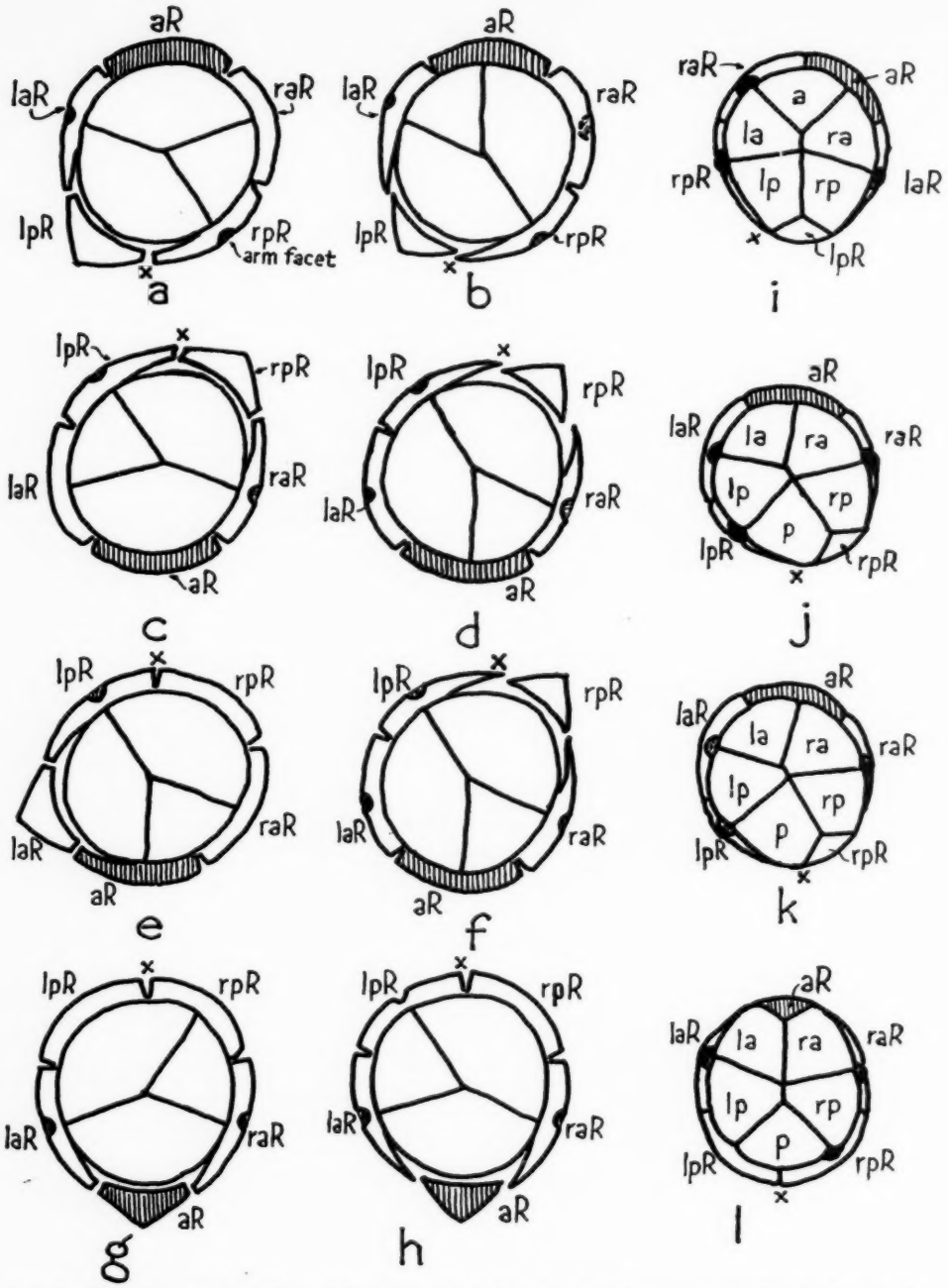



FIG. 3.—Drawings of the calices of immature blastoids, showing diagrammatically the designation of plates according to various methods of orientation. The anterior radial (aR) is shaded in each drawing and the position of the posterior interradius, as identified, is marked by *x*. *a*, *c*, *e*, *g*, represent *Mesoblastus glaber*, and the other figures represent *Pentremites princetonensis*. *a*, *b*, *i*, Orientation of dorsal and ventral views and designation of plates according to Croneis and Geis. *c*, *d*, *j*, Same corrected, no change of position of the anteroposterior axis as identified by Croneis and Geis. *e*, *f*, *k*, Calyx oriented so that the small basal is located in the right anterior interradius, the normal orientation of blastoids. *g*, *h*, *l*, Orientation of calyx based on plane of symmetry.

The orientation of different parts or aspects of an organism, whether blastoid, crinoid, or elephant, so that statements of relative positions conflict, is neither necessary nor useful. It is extremely confusing, and on all counts, it is strongly to be condemned. The left side of an elephant is left, whether viewed from below, from above, or from any other direction. Similarly, the left "distals" of a larval blastoid are the ones on the left side of the calyx, above the left radials. They are not adjacent to the right anterior and right posterior radials, as shown by Croneis and Geis (see fig. 3i). In turning from dorsal to oral views, they have transposed left and right. Correction is shown in figure 3j.

Up to this point, no question has been raised as to the identification by Croneis and Geis of the anteroposterior axis of their very immature blastoids. Possibly it is presumptuous to do so without having first-hand knowledge of these fossils. Yet, careful examination of the preliminary paper fails to discover just what actual evidence for the orientation accepted by Croneis and Geis was in their hands. Concerning the "second stage" that is identified as belonging to *Mesoblastus glaber* they state (p. 347) that

> neither mouth nor anus is observable as an enlarged portion of the sutures or as a separate pore but possibly their positions may be inferred from the eccentricities of the suture junctions on the oral surface. The mouth is probably located at the tip of the smaller right anterior distal (oral view), the anus at the tips of the two distals opposite.

Surely this cannot be accepted as very explicit testimony, and if other, better evidence is found in study of the "third stage" and "fourth stage," this is not mentioned. Nor is "post-larval" development much more satisfactorily treated. One specimen is noted (p. 350) in which

> the position of the anus is indicated by longer and steeper lateral slopes on the radials at the posterior interradius and by a much larger spiracle,

but there is still question as to correlation of parts between this and the younger specimens described. If any individual plates of the so-called larval stages are definitely indentifiable in this larger blastoid, this is not stated. The same comments apply to

> a slightly larger specimen, which unfortunately has distintegrated

and which

> provides information on the anal interradius

(p. 351). The description of specimens that are identified as belonging to *Pentremites princetonensis* contains no mention of anal structures or other definitive basis for recognition of the antero-posterior axis. Therefore, it seems that the case for the orientation adopted by Croneis and Geis is not convincingly given.

Presumably the position of the anteroposterior axis in immature specimens of the blastoids under discussion must be the same as in adult examples of these species. Croneis and Geis do not refer to this, and no mention of the position of the small basal in respect to anal structures has been found by me in published descriptions of adult specimens of *Mesoblastus glaber* (Meek and Worthen, 1869, 1873; Weller, 1920, p. 327) and *Pentremites princetonensis* (Ulrich, 1917; Weller, 1920, p. 314). The position of the small basal in other examples of these genera seems uniformly to be in the right anterior interradius, as is stated (Bather, 1900, p. 81; Springer, 1913, p. 161) to be invariably the rule among blastoids. I have made no effort to check this exhaustively, but inspection of numerous specimens of *Pentremites* and some other blastoids that are at hand and examination of published works do not show exceptions. Although Croneis and Geis (1940, p. 345) expressly state that theoretical discussions are reserved for a later paper, the question of orientation cannot be omitted from descriptive treatment, and it is disappointing, therefore, to read merely that the small basal in *Mesoblastus glaber* "apparently lies in the position of the right posterior interray (as viewed from below)" (see fig. 3a), which with correction for faulty orientation means the left posterior interray (fig. 3c). In *Pentremites princetonensis*, the small basal is reported (p. 352) to occupy "the left anterior interray (basal view)" (see fig. 3b), which may be corrected to read right anterior interray (fig. 3d). Thus, the latter species seems to be normal and the former to be abnormal, according to identifi-

cations of the anteroposterior axis in the two species that are given. It is necessary to point out that the calices are consistently oriented as regards characters of the radial and "distal" circlets, and that a difference seems unquestionably to appear in the disposition of plates of the basal circlet in the two species. Drawings showing distribution of plates on the basis of "normal" orientation of the anteroposterior axis, so as to place the small basal in the right anterior interradius, are given in figures 3e, 3f, and 3k.

Finally, it seems worthwhile to direct attention to another orientation that is based on symmetry of the radial and "distal" circlets. This is shown diagrammatically in figures 3g, 3h, and 3l. In adult blastoids and in many crinoids the plane of bilateral symmetry (except as concerns the basals) coincides with position of the anteroposterior axis. The appearance of the "distal" circlet of the young blastoids is closely similar to that of the oral circlet of *Allagecrinus*, *Callimorphocrinus*, and other microcrinoids, if the calyx of the blastoid is oriented on the hypothesis that the plane of symmetry coincides with the anteroposterior axis (see figs. 1 and 3l). It is evident, however, that orientation in this manner brings the small basal into anomalous positions, in the interray between the right anterior and right posterior rays in the case of *Mesoblastus glaber* (fig. 3g), and in the interray between the left anterior and left posterior rays in the case of *Pentremites princetonensis* (fig. 3h). This is not very helpful. Obviously, it is the definite identification of characters belonging to the anus, or features reliably usable for recognition of the posterior interradius that must show the correct orientation. Further reports on the studies by Croneis and Geis are awaited with great interest.

## REFERENCES


BASSLER, R. S., *1938*, *Fossilium Catalogus, Animalia*, Pelmatozoa Paleozoica: Pt. 83, pp. 1–194, edit. W. Quenstedt, W. Junk, Gravenhage.

BATHER, F. A., *1900*, The Echinoderma: *A Treatise on zoology*, by E. Ray Lankester; pt. 3, pp. 1–344, A. and C. Black, London.

BRANSON, E. B., *1938*, Stratigraphy and paleontology of the lower Mississippian of Missouri, pt. 1: *Univ. Missouri Studies*, vol. 13, pp. 1–208, pls. 1–20.

CARPENTER, P. H., and ETHERIDGE, R., JR., *1881*, On *Allagecrinus*, the representative of a new family from the Carboniferous limestone series of Scotland: *Annals and Mag. Nat. History*, ser. 5, vol. 7, pp. 281–298, pls. 15, 16.

CRONEIS, CAREY, and GEIS, H. L., *1940*, Microscopic Pelmatozoa: Pt. 1, Ontogeny of the Blastoidea: *Jour. Paleontology*, vol. 14, pp. 345–355.

KIRK, EDWIN, *1936*, A new *Allagecrinus* from Oklahoma: *Washington Acad. Sci., Jour.*, vol. 26, pp. 162–165, text fig. 1.

——, *1937*, *Clistocrinus*, a new Carboniferous crinoid genus: *Washington Acad. Sci., Jour.*, vol. 27, pp. 105–111, figs. 1–8.

MOORE, R. C., *1940*, Relationships of the family Allagecrinidae, with description of new species from Pennsylvanian rocks of Oklahoma and Missouri: *Denison Univ. Sci. Labs., Bull.*, vol. 35, pp. 55–137, pls. 2, 3.

MOORE, R. C., and PLUMMER, F. B., *1940*, Crinoids from the Upper Carboniferous and Permian strata in Texas: *Texas, Univ. Bull.* 3945, pp. 9–468, pls. 1–21, figs. 1–78.

PECK, R. E., *1935*, Growth stages of *Allagecrinus americanus* Rowley: *Jour. Geology*, vol. 43, pp. 765–770, fig. 1.

——, *1936*, Lower Mississippian microcrinoids of the Kinderhook and Osage groups of Missouri: *Jour. Paleontology*, vol. 10, pp. 282–293, pls. 46, 47.

ROWLEY, R. R., *1895*. Description of a new genus and five new species of fossils from the Devonian and Sub-carboniferous rocks of Missouri: *Am. Geologist*, vol. 16, pp. 217–223.

SPRINGER, FRANK, *1913*, Blastoidiea and Crinoidea, in Zittel-Eastman, *Textbook of Palaeontology*, vol. 1, pp. 161–243, Macmillan, New York, London.

STRIMPLE, H. L., *1940*, Some new crinoid species from the Morrow subseries: *Bull. Am. Paleontology*, vol. 25, no. 91, pp. 3–11, pl. 1.

ULRICH, E. O., *1917*, *Pentremites princetonensis* Ulrich, n. sp., in Charles Butts, Mississippian formations of western Kentucky; *Kentucky Geol. Survey*, pp. 1–272, pls. 1–11.

WACHSMUTH, CHARLES, *1882*, Descriptions of two new species of Crinoidea from the Chester limestone and Coal measures of Illinois: *Illinois State Mus. Nat. History* Bull. 1, pp. 40–43.

WANNER, JOHANN, *1924*, Die permischen Echinodermen von Timor, Teil 2: *Paläontologie von Timor*, Lief. 14, pp. 1–79, pls. 1–8.

——, *1929*, Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor, 1, Allagecrinus, 2, Hypocrinites: *Dienst van den Mijnbouw in nederl.-Indi; Wetensch. Meddelelser. ser.* no. 11, p. 1–116, pls. 1–7, text figs. 1–16.

——, *1937*, Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor, VIII–XIII: *Palaeontographica*, Suppl. Bd. 4, Abt. 4, Lief. 2, pp. 57–212, pls. 5–14, text figs. 1–82, Stuttgart.

WELLER, J. M., *1930*, A group of larviform crinoids from lower Pennsylvanian strata of the Eastern Interior Basin: *Illinois Geol. Survey*,

*Repl. Investigations* 21, pp. 1–38, pls. 1, 2.

WELLER, STUART, *1920*, The geology of Hardin County (Illinois): *Illinois Geol. Survey, Bull.* 41, pp. 1–416, pls. 1–11.

WRIGHT, JAMES, *1932*, The Scottish species of *Allagecrinus: Geol. Mag.*, vol. 69, pp. 337–366, pls. 32–35, text figs. 1–35.

——, *1933*, Two new crinoids from the Scottish Carboniferous limestones, with notes on the Allagecrinidae: *Geol. Mag.*, vol. 70, pp. 193–208, pls. 13, 14, text figs. 1–15.

——, *1939*, The Scottish Carboniferous Crinoidea: *Roy. Soc. Edinburgh, Trans.*, vol. 60, pt. 1, no. 1, pp. 1–78, pls. 1–12, text figs. 1–85.

---

## EARLY GROWTH STAGES OF CARBONIFEROUS MICROCRINOIDS AND BLASTOIDS—A DISCUSSION

CAREY CRONEIS, University of Chicago, Chicago, Illinois

Professor Moore's comments on Croneis and Geis' paper "Ontogeny of the Blastoidea" in large part anticipate discussion of points reserved for treatment in the second paper of the series, specifically promised in "Microscopic Pelmatozoa: Part I." Accordingly, detailed analyses of his various criticisms will be found in "Microscopic Pelmatozoa: Part II, Orientation of the Blastoidea" which will appear in an early issue of this Journal.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 6, PP. 584–589, NOVEMBER, 1940

# MISELLINA AND BREVAXINA, NEW PERMIAN FUSULINID FORAMINIFERA

HUBERT G. SCHENCK and M. L. THOMPSON
Stanford University, California, and New Mexico School of Mines, Socorro, New Mexico

ABSTRACT—*Doliolina* Schellwien, 1902 (a foraminifer), is preoccupied by *Doliolina* Borgert, 1894 (a tunicate). Because of complications in the interpretation of the foraminiferal genus as originally proposed and subsequently interpreted, a new genus (*Misellina:* type *Doliolina ovalis* Deprat) is here suggested rather than a simple renaming of the homonym. *Brevaxina* (type: *Doliolina compressa* Deprat) is proposed as a new subgenus of *Misellina*. A synopsis of the subfamily Verbeekininae (family Fusulinidae) summarizes the arrangement of these Permian fusulinid Foraminifera.

DOLIOLINA Schellwein, 1902, refers to a fusulinid foraminiferal genus. This name is preoccupied by *Doliolina* Borgert, 1894, a tunicate. Since it is generally recognized by specialists that "*Schwagerina*" *lepida*, the genotype of *Doliolina* Schellwien, either is an end member of the biological category at present going under the generic name *Doliolina* or is congeneric with the type species of *Pseudodoliolina* Yabe and Hanzawa, we are allowing *Doliolina* Schellwien to remain stillborn and are here selecting a more representative species to serve as the type of the category left without a name because of the homonym. Therefore, we are proposing the name *Misellina* as a new genus, with *Doliolina ovalis* Deprat (1915, pp. 15–16, pl. 3, figs. 1–4, text fig. 8) as the genotype. We are also introducing *Brevaxina* as a new subgenus of *Misellina* with *Doliolina compressa* Deprat (1915, pp. 14–15, pl. 3, figs. 10–14, text fig. 7) as the type of the subgenus. Both of these species are from the Permian of Cam-mon, French Indo-China.

### THE FORAMINIFER DOLIOLINA

Ernst Schellwien in 1898 (p. 238) proposed the name *Möllerina*, typified by *Schwagerina lepida* Schwager, 1883, for a subgenus of *Fusulina*. He overlooked the fact that E. O. Ulrich, in 1886 (pp. 34–35), used the name *Moellerina* for a genus of "Foraminifera" from the Devonian of Indiana—genotype by monotypy, *M. greeni* Ulrich, 1886. (It has been suggested by some specialists of the trochiliscids that *M. greeni* may be a chara; see Peck, 1934, p. 86.) In 1902, Schellwien (p. 67, footnote 2) introduced the name *Doliolina* for the late Paleozoic fusulinid foraminifer, and at that time he apparently considered it as having the rank of a genus.

### THE TUNICATE DOLIOLINA

Borgert in 1894 (p. 14) proposed the name *Doliolina* as a subgenus of *Doliolum*. Mention of the nomenclature of *Doliolum*, with reference to *Doliolina*, is given in Opinion 76 of the International Commission on Zoological Nomenclature (1922, pp. 64–66). The type of the subgenus is here designated as *Doliolum krohni* Herdman, 1888. The International Rules of Zoological Nomenclature, Article 6, require that a subgenus is to be treated as a genus for the purpose of nomenclature—

> . . . from a nomenclatural standpoint they are coordinate, that is, they are of the same value.

Hence, the subgeneric name *Doliolina* Borgert, 1894, has priority over the generic name *Doliolina* Schellwien, 1902.

### RELATIONSHIPS OF THE FORAMINIFER

That *Doliolina* Schellwien is a homonym and should be renamed is thus an inescapable conclusion, considered only from a nomenclature angle. A biological problem, however, complicates the case. This problem is the relationship of "*Doliolina*" to *Pseudodoliolina*. The latter genus was named by Yabe and Hanzawa in 1932 (pp. 40–43), with *Pseudodoliolina ozawai* Yabe and Hanzawa as the genotype. *Pseudodoliolina* was erected on the assumption that the spirotheca of its genotype consists of a thick

tectum and no keriotchea. Thompson and Foster (1937, pp. 138–140) proved that this is erroneous, for after the tenth volution the spirotheca of *P. ozawai* has a structure like that of "*Doliolina*" *lepida*. Since the fundamental reason for establishing *Pseudodoliolina* is untenable, this genus would appear to be a synonym of *Doliolina* Schellwien. But as *Doliolina* is a homonym, it follows that *Pseudodoliolina* may be employed, other factors remaining equal. By such logic, the species from the Permian limestone on the Yangtze River in the Province of Hupeh first described as *Schwagerina lepida*, next called *Möllerina lepida* and later referred to as *Doliolina lepida*, would now be cited as *Pseudodoliolina lepida* (Schwager). The original specimens of the type species of *Doliolina*, the foraminifer, would thus become, through the fortunes of taxonomy, the "false dolioline."

Still another factor enters into the problem. Gubler (1935, pp. 68–71) suppressed *Pseudodoliolina* Yabe and Hanzawa as a synonym of *Doliolina* Schellwien, based on the belief that *P. ozawai* is the megalospheric form of *Schwagerina lepida* Schwager, Schwager's types being the microspheric form of the same species. Thompson and Foster (1937) admitted that the juvenarium of "*Doliolina*" is endothyroid, in contrast to the large proloculum of *P. ozawai*. This feature, supplemented by certain other morphological differences, influenced them to recognize tentatively *Pseudodoliolina* and *Doliolina* as valid genera. We have reviewed the evidence critically and have reached the following conclusions:

(1) The holotype of *Pseudodoliolina ozawai* is specifically distinct from the type specimens of *Schwagerina lepida*, and therefore Gubler was incorrect in supposing that they were synonymous because of dimorphism. Representatives of these two species can be distinguished by the following differences: Schwager's types of *S. lepida* are much larger than the holotype of *P. ozawai* or any topotype specimens of *P. ozawai* which we have from Akasaka. Schwager's largest illustrated axial section measures 6.56 mm. in length and 3.59 mm. in width, giving a form ratio of about 1:1.8. The holotype of *P. ozawai* measures about 4.2 mm. in length and 1.9 mm. in width, giving a form ratio of about 1:2.2. Also, the average size of mature specimens of *P. ozawai* in our collections from Akasaka measure about 4.9 mm. in length and 2.0 mm. in width. The form-ratios of eight specimens are 1:2.2 to 1:2.8. The spirotheca of *P. ozawai* is much thinner than the spirotheca of *S. lepida*. In the earlier volutions of *S. lepida* the three layers of the spirotheca are distinct, whereas, in *P. ozawai* these layers can be distinguished only in the outer two or three volutions of mature specimens. Gubler (1935, p. 97) states that the spirotheca of one of Schwager's types of 16 volutions measures 30 to 35 microns in the tenth volution, which is greater than the thickness of the spirotheca in any portion of specimens of *P. ozawai*. The juvenarium of *S. lepida* is endothyroid, and the proloculum is small. In *P. ozawai* the juvenarium is somewhat fusiform, and the proloculum is large. *S. lepida* is inflated in the midportion of the shell at maturity, and *P. ozawai* is essentially cylindrical in the midportion of the shell at maturity. The parachomata of *S. lepida* are broader and lower than the parachomata of *P. ozawai*.

(2) We are referring *Schwagerina lepida* with question to the genus *Pseudodoliolina*, realizing that it may be considered by some more closely related to the genotype of *Misellina*, new genus. The original types of *S. lepida* have endothyroid juvenaria and small prolocula in contrast to those of *P. ozawai*, the genotype of *Pseudodoliolina*, and their parachomata are lower and broader than the parachomata of *P. ozawai*. However, their spirotheca are more nearly comparable in thickness to the spirotheca of *P. ozawai* than to the spirotheca of *D. ovalis*, the genotype of the new genus *Misellina*.

Whatever others may decide concerning the relationship between "*Doliolina*" *lepida* and *Pseudodoliolina ozawai*, specialists will agree that *lepida* does not occupy a central position in the morphological distribution curve of the biological unit known as "*Doliolina*." That is to say, *lepida* is not a typical representative of what is usually interpreted to be "*Doliolina*."

A more representative species is *Doliolina ovalis* Deprat (1915, p. 15). This species, whose figured axial section measures 2.7 mm. in length, exhibits the shell characters

commonly associated with the name "*Doliolina*." We are therefore taking this species as the genotype of a new genus: *Misellina* Schenck and Thompson.

Moreover, the fossil described and illustrated by Deprat as *Doliolina compressa* warrants recognition as the type of a new subgenus of *Misellina*, which we are proposing to call *Brevaxina* Schenck and Thompson. This species is based upon a specimen 2 mm. in height. The form ratio of the figured axial section of *Doliolina ovalis* is about 1:1.69, whereas the form ratio of *Doliolina compressa* is about 1:0.58. In the subfamily Fusulininae, for comparison, representatives of *Fusulinella* Möller and *Staffella* Ozawa have identical spirothecal structures, and their septal fluting and other internal features are essentially the same. Indeed, the generic distinction between *Fusulinella* and *Staffella* is based mainly upon a form ratio difference of no greater magnitude than that just stated. We conclude that we are justified in establishing this new subgenus with *Doliolina compressa* Deprat as the type of the subgenus.

## SYNOPSIS OF THE SUBFAMILY VERBEEKININAE

Although Dunbar and Henbest (1930, p. 363) employed the subfamily name Dolioliniae in lieu of Verbeekininae, as did Gubler in 1935, Thompson (1936, pp. 193–201) presented ample evidence for retaining Verbeekininae. The subfamily name Verbeekininae is adopted by Dunbar and Skinner (1937, p. 572). In order that our views on the arrangement of this subfamily will be clear, we present the following synopsis of these foraminifers:

### Subfamily VERBEEKININAE Staff and Wedekind, 1910

Verbeekininae STAFF and WEDEKIND, *1910*, Geol. Inst. Bull., Univ. Upsala, vol. 10, p. 114.

Shell subspherical to fusiform; axis of coiling greater or less than the thickness of the shell; planispiral; foramina present in all genera but developed only in the outer volutions of representatives of earlier genera; parachomata present in all forms with the possible exception of primitive representatives of *Eoverbeekina;* wall composed of a tectum, keriotheca, and a thin inner layer; septula absent; tunnel absent in all genera except *Eoverbeekina;* septa unfluted.

*Geological range.*—Permian.

#### Genus EOVERBEEKINA Lee, 1933

*Eoverbeekina* LEE, *1933*, Nat. Research Inst. Geology, Mem., no. 14, p. 18; CHEN, *1934*, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 103; THOMPSON and FOSTER, *1937*, Jour. Paleontology, vol. 11, p. 135; DUNBAR and SKINNER, *1937*, Texas Univ. Bull. 3701, p. 573.

Genotype, *Eoverbeekina intermedia* Lee, 1933 (by original designation).

Shell moderately large, spherical at maturity, lenticular during early stages of growth; planispiral; tunnel present throughout the shell, narrow and high in early volutions but low and slit-like in later volutions; foramina absent in early volutions but well developed in outer volutions; parachomata poorly developed in outermost volutions; wall composed of a tectum and a keriotheca; septa unfluted.

Representatives of this genus can be distinguished from all other members of this subfamily by the lenticular juvenarium, the presence of a tunnel, and the absence of foramina and parachomata in the earlier volutions.

So far as we can determine, only two species have been described which are referable to this genus: *E. intermedia* Lee, the genotype, and *E. cheni* Thompson and Foster, 1936.

#### Genus VERBEEKINA Staff, 1909

*Fusulina* (part) BRADY, *1875*, Geol. Mag., n. s., dec. 2, vol. 2, p. 537; GEINITZ, *1876*, Palaeontographica, Bd. 22, p. 399.

*Schwagerina* (part) MÖLLER, *1879*, Imp. Acad. Sci. St. Pétersbourg, Mém., sér. 7, t. 27, no. 5, p. 9; ROEMER, *1880*, Lethaea Geognostica I, p. 277; SCHWAGER, *1883*, Richthofen's China, Bd. 4, p. 135; YABE, *1902*, Geol. Soc. Tokyo, Jour., vol. 9, p. 1; DEPRAT, *1912*, Service géol. Indochine Mém., vol. 1, fasc. 3, p. 40; COLANI, 1924, Service géol. Indochine, Mém., vol. 11, fasc. 1, p. 108.

*Fusulina* (*Möllerina*) (part) SCHELLWIEN, *1898*, Palaeontographica, Bd. 44, p. 258.

*Doliolina* (part) SCHELLWIEN, *1902*, Physikalisch-ökonomische Gesellschaft zu Königsberg, Schriften, 43, pp. 67–68; DUNBAR and HENBEST, *1930*, Am. Jour. Sci., 5th ser., vol. 20, p. 363; TAN, *1933*, Dienst van den Mijnbouw, in Nederl.-Indië, Wetensch. Meddelelser, no. 25, pp. 57–65.

*Doliolina* (*Verbeekina*) STAFF, *1909*, Neues Jahrbuch, Beilage-Band, Abt. B, 27, p. 476;

OZAWA, *1925*, Tokyo Imp. Univ. Jour., Coll. Sci. vol. 45, art. 4, p. 25.

*Schwagerina* (*Verbeekina*) DEPRAT, *1913*, Service géol. Indochine, Mém., vol. 2, fasc. 1, p. 45.

*Verbeekina* STAFF and WEDEKIND, *1910*, Geol. Inst., Bull., Univ. Upsala, vol. 10, p. 114; OZAWA, *1925*, Tokyo Imp. Univ., Jour. Coll. Sci. vol. 45, art. 6, p. 48; DUNBAR and CONDRA, *1927*, Nebraska Geol. Survey, ser. 2. Bull. 2, p. 67; GALLOWAY, *1933*, A manual of Foraminifera, p. 407; CHEN, *1934*, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 101; THOMPSON, *1936*, Jour. Paleontology, vol. 10, pp. 193–201; GUBLER, *1935*, Soc. géol. France, Mém., n. s., tome 11, fasc. 4, mém. 26, pp. 67–68; DUNBAR and SKINNER, *1937*, Texas Univ. Bull. 3701, p. 573.

Genotype, *Fusulina verbeeki* Geinitz, 1876 (by original designation).

Shell large, spherical to subspherical, planispiral; juvenarium endothyroid; proloculum minute; volutions numerous, reaching 21 in number in mature individuals of some species; chambers numerous; septa unfluted; foramina developed throughout the shell; parachomata rudimentary in inner volutions and well developed in outer volutions; spirotheca composed of a tectum and a keriotheca, with a thin layer on the inner side of the spirotheca.

Representatives of *Verbeekina* can be distinguished from other members of this subfamily by their subspherical shape throughout the shell, large size, poor development of the parachomata in inner volutions, absence of a tunnel, and the development of the foramina throughout the shell.

In addition to the genotype, we are referring the following forms to the genus *Verbeekina:*

*Verbeekina verbeeki* var. *volzi* Staff, 1909; *Schwagerina douvillèi* Deprat, 1912; *Schwagerina* (*Verbeekina*) *pseudoverbeeki* Deprat, 1913; *Verbeekina verbeeki* var. *sphaera* Ozawa, 1925; *Schwagerina* (*Verbeekina*) *deprati* Yabe, 1924 [Hayasaka]; *Verbeekina minor* Chen, 1934; *Verbeekina akasakensis* Thompson, 1936; *Verbeekina heimi* Thompson and Foster, 1936; *Verbeekina grabaui* Thompson and Foster, 1936.

### Genus MISELLINA Schenck and Thompson, n. gen.

*Doliolina* (part) of authors.

Genotype, *Doliolina ovalis* Deprat, 1915.

Shell small, ellipsoidal to subspherical or laterally compressed, axis of coiling greater or less than the thickness of the shell, having form-ratios of 1:0.58 to 1:1.6; volutions usually less than eight in number at maturity, chambers numerous; proloculum small; juvenarium endothyroid; spirotheca thick, composed of a tectum, a thick keriotheca and a thin inner layer, foramina developed throughout the shell; parachomata developed throughout the shell; septa unfluted.

Representatives of *Misellina*, new genus, may be distinguished from other members of this subfamily by their small size, thick spirotheca, small prolocula, the shape of their shells, and their low and broad parachomata.

### Subgenus MISELLINA Schenck and Thompson, n. subgen.

Subgenotype, *Doliolina ovalis* Deprat, 1915

Shell small, ellipsoidal, axis of coiling the greatest diameter; juvenarium endothyroid, proloculum small; spirotheca thick; parachomata broad and low.

In addition to the subgenotype, the following species and variety seem to us referable to the subgenus *Misellina: Doliolina claudiae* Deprat, 1912; *Doliolina aliciae* Deprat, 1912; *Doliolina subelliptica* Deprat, 1915; *Doliolina parvicostata* Deprat, 1915; *Doliolina termieri* Deprat, 1915; *Doliolina minor*, Deprat, 1915; *Doliolina minima* Lange, 1925; *Doliolina termieri* var. *pamirensis* Doutkevitch, 1934.

### Subgenus BREVAXINA Schenck and Thompson, n. subgen.

Subgenotype, *Doliolina compressa* Deprat, 1915

Shell small, subspherical and laterally compressed; axis of coiling the shortest diameter, the subgenotype and only described representative has a form ratio of 1:0.58; umbilical areas depressed; proloculum small; juvenarium endothyroid; spirotheca thick, parachomata high and broad.

The type species of this subgenus can be distinguished from representatives of the typical subgenus by its large form ratio and depressed umbilical areas.

### Genus PSEUDODOLIOLINA Yabe and Hanzawa, 1932

*Doliolina* (part) authors prior to 1932; Gubler, *1935*, Soc. Géol. France, Mém., n. s., t. 11, fasc. 4, no. 26, pp. 68–71.

*Pseudodoliolina* Yabe and Hanzawa, *1932*, Imp. Acad. Japan, Proc., vol. 8, no. 2, pp. 41–42; Galloway, *1933*, A manual of Foraminifera, p. 410; Dunbar, *1933*, in Cushman, Foraminifera, Cushman Lab. Foram. Research, Spec. Pub. no. 4, p. 139; Chen, *1934*, Palaeontologia Sinica, ser. B, vol. 4, fasc. 2, p. 100; Thompson and Foster, *1936*, Jour. Paleontology, vol. 11, pp. 138–140; Dunbar and Skinner, *1937*, Texas Univ. Bull. 3701, p. 575.

Genotype, *Pseudodoliolina ozawai* Yabe and Hanzawa, 1932 (by original designation).

Shell of medium size, elongate melon-shaped to slightly fusiform, planispiral; juvenarium not typically set off from remainder of shell; proloculum typically moderately large; volutions numerous; chambers numerous; septa unfluted; foramina developed throughout the shell; parachomata developed throughout the shell; narrow and high and reaching the top of the chambers just anterior of the septa—in some species, like *P. dunbari* (Gubler), the parachomata reach the top of the volution almost completely across the chamber and appear as septula in axial sections; spirotheca typically composed of only one recognizable layer in the inner volutions, but in the outer two or three volutions of mature forms the spirotheca is composed of a tectum, a thin inner layer and a central layer of light material, which apparently corresponds to the keriotheca of other genera.

Representatives of *Pseudodoliolina* can be distinguished from other members of this subfamily by their thin spirotheca, narrow and high parachomata, elongated subcylindrical shells, and large prolocula—the exceptions to the last characteristic are the species *S. lepida* and *D. douvillĕi* which we are referring to this genus with question.

In addition to the genotype, the following described forms seem to us referable to the genus *Pseudodoliolina:* ?*Schwagerina lepida* Schwager, 1883; ?*Schwagerina lepida* var. *ellĭpsoidalis* Schwager, 1883; *Doliolina pseudolepida* Deprat, 1912; *Doliolina major* Deprat, 1914; *Doliolina* [*lepida* var.] *lettensis* Schubert, 1915; ?*Doliolina douvillĕi* Gubler, 1936; *Doliolina dunbari* Gubler, 1936.

Through the generosity of Dr. W. O. Dietrich of the University of Berlin, we have been able to study a part of the syntypes of *Schwagerina lepida* Schwager. These specimens are all from the limestone on the right bank of the Yantze River, opposite Ki-tschou, Hupei Province, China. This limestone was designated by Schwager (1883, p. 107) as horizon a(1). Schwager states that this rock contains numerous specimens of the cylindrical variety of *S. lepida;* he does not mention any other fusulinids from it. This collection reached us after the manuscript was in press but we feel that a brief discussion of these types should be given at this time.

It is evident from the following descriptions that the type specimens of *S. lepida* and of *Pseudodoliolina ozawai* Yabe and Hanzawa do not represent the same species, as proposed by Gubler (1935). The spirotheca of the type specimens of *S. lepida* is thicker, the proloculum is smaller, the midportion of the shell is more highly inflated, and the juvenarium of *S. lepida* is endothyroid and has a small form ratio, even in the specimen with an unusually large proloculum.

*Axial section passing through the center of the proloculum.*—Stanford Univ. Paleont. Type Coll. Syntype no. 6730.

Shell of 14.5 volutions (outer 1.5 volutions poorly preserved), subcylindrical in shape and slightly inflated in midportion, with broadly rounded poles; diameter of inner 13 volutions 2.26 mm. and length 4.46 mm. (twice half-length), giving a form ratio of 1:2; inside diameter of proloculum 45 microns; form ratio of third volution 1:0.79; height of chambers in twelfth volution 147 microns; height of parachomata in twelfth volution 80 microns; spirotheca composed of tectum, coarsely alveolar keriotheca, and a lower layer; thickness of keriotheca in fifth volution 10 microns and in twelfth volution 24 microns; height of chambers in twelfth volution 147 microns and height of parachomata in same volution 80 microns; number of foramina in twelfth volution 26 to 30.

The angle between the axis of coiling of the outer volutions and the axis of coiling of the first volution is about 90°, and the angle between the axis of the outer volutions and the axis of the second and third volutions is 48°. All three layers of the spirotheca are clearly visible from the fifth volution outward.

*Parallel sagittal section cutting the first volution.*—Stanford Univ. Paleont. Type Coll. Syntype no. 6731.

Specimen of 13 volutions, thickness 2.23 mm.; thickness of keriotheca in middle of chambers of the twelfth volution 21 to 24 microns; septal count from the fifth to twelfth volution 14, 16, 16, 20, 20, 20, 20, and 26. The keriotheca becomes markedly thicker adjacent to the septa and

measures 42 to 48 microns just before passing down the septa in the twelfth volution.

*Axial section tangential to the outer part of the proloculum.*—Syntype no. 1, M. L. Thompson Collection.

Shell of 15 volutions (outer two volutions incomplete), subcylindrical in shape and becoming more highly inflated in the mid-portion with growth; poles very broadly rounded; inner 13 volutions 2.45 mm. in diameter and 4.43 mm. in length, giving a form ratio of 1:1.8; form ratio of third volution 1:0.9; height of chambers in twelfth volution 175 microns; height of parachomata in twelfth volution 56 microns; thickness of keriotheca in fifth volution 10 microns and in twelfth volution 18 to 21 microns; there are 30 to 34 foramina in the twelfth volution.

The angle between the axis of coiling of the inner two volutions and the axis of coiling of the outer volutions measures about 10°.

*Axial section passing through the center of the proloculum.*—Syntype no. 2, M. L. Thompson Collection.

Shell of 15 volutions (outer two volutions poorly preserved), subcylindrical, becoming inflated in midportion with growth; inner 13 volutions 2.73 mm. in diameter and 5.0 mm. in length; form ratio of inner 13 volutions 1:1.83; inside diameter of proloculum 95 microns; form ratio of third volution 1:1.1; height of chambers in twelfth volution 194 microns; height of parachomata in twelfth volution 65 microns; keriotheca measures 10 microns in the fifth volution and 18 to 21 microns in the twelfth volution; there are 30 foramina in the twelfth volution.

The angle between the axis of coiling of the first volution and the axis of coiling of the outer volutions measures 14 degrees.

## REFERENCES


BORGERT, A., *1894*, Die Thaliacea der Plankton-Expedition, C. Vertheilung der Doliolen, *Ergeb. Plankton Expedition d. Humboldt-Stiftung*, vol. 2. E. a. C., pp. 1–68, pls. 1–8.

DEPRAT, J., *1915*, Les Fusulinidés des calcaire carboniériens et permiens du Tonkin, du Laos, et du Nord-Annam: *Service géol. Indochine, Mém.*, t. 4, fasc. 1, pp. 1–30, pls. 1–3, text figs. 1–11.

DUNBAR, C. O., and HENBEST, L. G., *1930*, The fusulinid genera *Fusulina*, *Fusulinella*, and *Wedekindella: Am. Jour. Sci.*, ser. 5, vol. 20, pp. 357–364.

DUNBAR, C. O., and SKINNER, J. W., *1937*, Permian Fusulinidae of Texas: *Texas Univ., Bull.* 3701, pt. 2, pp. 517–825, pls. 42–81.

GUBLER, J., *1935*, Les Fusulinidés du Permien de l'Indochine: *Soc. géol. France, Mém.* n. s., t. 11, fasc. 4, Mém. 26, pp. 1–173, pls. 1–8.

INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE, *1922*, Smithsonian Misc. Coll., vol. 73, no. 1, publ. 2657, pp. 1–73.

PECK, R. E., *1934*, The North American Trochiliscids, Paleozoic Charophyta: *Jour. Paleontology*, vol. 8, no. 2, pp. 83–119, pls. 9–13.

SCHELLWIEN, E., *1898*, Die Fauna des karnischen Fusulinenkalks, Theil II., Foraminifera: *Palaeontographica*, Bd. 44, pp. 237–282, pls. 17–24, text-figs. 1–7.

——, *1902*, Trias, Perm und Carbon in China: *Physikalisch-ökonomische Gesellschaft zu Königsberg, Schriften*, Jahrg. 43, pp. 59–78, pl. 3.

SCHWAGER, C., *1883*, Carbonische Foraminiferen aus China und Japan: in Richthofen's *China*, Bd. 4, pp. 106–159, pls. 15–18.

THOMPSON, M. L., *1936*, The fusulinid genus *Verbeekina: Jour. Paleontology*, vol. 10, no. 3, pp. 193–201, pl. 24.

THOMPSON, M. L., and FOSTER, C. L., *1937*, Middle Permian fusulinids from Szechuan, China: *Jour. Paleontology*, vol. 11, no. 2, pp. 126–144, pls. 23–25.

ULRICH, E. O., *1886*, Descriptions of new Silurian and Devonian fossils: *Contr. Am. Paleontology*, vol. 1, no. 1, pp. 3–35.

YABE, H., and HANZAWA, S., *1932*, Tentative classification of the Foraminifera of the Fusulinidae: *Imp. Acad. Japan, Proc.*, vol. 8, no. 2, pp. 40–43.


MANUSCRIPT RECEIVED BY EDITOR FEBRUARY 23, 1940.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 6, PP. 590–597, NOVEMBER, 1940

# CONTRIBUTIONS TO NAUTILOID NOMENCLATURE

CURT TEICHERT
University of Western Australia, Crawley, Western Australia

SEVERAL years ago I undertook, at the request of Professor Schindewolf, to prepare the volume on the Nautiloidea for the new Handbook of Palaeozoology, the first parts of which have recently been issued. In preparation of this work a survey of established nautiloid genera had to be made, and in the following lines a few observations of nautiloid generic nomenclature are communicated, since the Handbook would not be the place to discuss purely nomenclatural matters. This survey includes only a portion of the existing nomenclatural problems. It may be necessary to present additional material at some future date.

I am under obligation to Dr. J. B. Knight, Princeton University, and to Dr. A. B. Walkom, Sydney, for information kindly supplied with regard to certain literature references.

## NEW GENERA

*Liroceras*, gen. nov. is here proposed for forms which have been referred to *Coloceras* Hyatt (1893, p. 449), not *Coloceras* Nitzsch (1882, p. 42). The genotype of *Coloceras* Hyatt is *Coloceras hyatti* Miller, Dunbar and Condra (1933, p. 132) from the Lower Carboniferous of Belgium. However, as Miller, Dunbar and Condra have pointed out, that species is very imperfectly known, and it seems inadvisable to make it the genotype of a valid genus. *Coloceras liratum* Girty (1911), redescribed by Miller, Dunbar and Condra in 1933 (pp. 132–134), is, therefore, here chosen as the genotype of the new genus *Liroceras*. In consequence, *Coloceras* Hyatt, now restricted to its poorly known genotype, becomes either a *genus inquirendum* which need not be renamed, or, more probably, a subjective synonym of *Liroceras*. *Liroceras*, as here understood, comprises all the species referred to *Coloceras* by Miller, Dunbar and Condra in 1933 as well as all the American species of "*Coloceras*" described after that date. It differs from *Stearoceras* Hyatt in the straight or almost straight course of its sutures and by the absence of an annular lobe. Its distribution is world-wide in strata of Upper Carboniferous (Pennsylvanian) and Lower Permian age.

### BALTICOCERAS, gen. nov.

Genotype: *Trematoceras discors* Eichwald (1857, p. 201). Eichwald established the genus *Trematoceras* in 1851 (p. 123) for the two species *Orthoceratites schlotheimii* Steininger (from Wissenbach) and *Orthoceratites elegans* Münster. The only species actually described by him under this generic name, is, however, *Trematoceras discors* from the Wesenberg limestone of Estonia (1857, p. 201; 1860, pp. 1259–1261). The genus was long regarded as a synonym of *Bactrites* Sandberger, although none of the species referred to it by Eichwald are related to that genus. In 1930, I erroneously based my conception of the genus on *Trematoceras discors* and, after having examined the holotype of that species, I stated (p. 273) that Eichwald's description of it was essentially correct and that the genus was well established. Later on, in 1933, Schindewolf (p. 18) selected *Orthoceratites elegans* Münster as the genotype of *Trematoceras* and correctly pointed out that *Trematoceras discors* was an entirely different form. As thus established, *Trematoceras* Eichwald is a Triassic genus and seems to be the last of the Pseudorthoceratidae, which are so widely distributed in the Middle and Late Palaeozoic. A new generic name is, therefore, necessary for *Trematoceras discors* and *Balticoceras* is here proposed for it.

Diagnosis: Orthoconic shells, semicircular in cross-section; broadly flattened ventral side, evenly rounded semi-circular dorsal side; siphuncle marginal; septal necks orthochoanitic. At present known only from the Wesenberg limestone (Etage E) of Estonia (Middle Ordovician). The relationship of the genus is apparently with *Tripteroceras* and allied genera.

### HERACLOCERAS, nom. nov.

*Heracloceras*, nom. nov., is here proposed to replace *Gigantoceras* Hyatt (1900, p. 527),

preoccupied by *Gigantoceras* Holland (1893, p. 549). Genotype, *Gyroceratites (?Nautilus) inelegans* Meek (1871, p. 89). Devonian of Ohio.

GENERA INQUIRENDA

Genera are enumerated below which have been established in accordance with the International Rules and are technically valid, but which cannot be recognized on the basis of their original description. Such names must still be listed in catalogues and bibliographic indices, though they must be omitted from systematic and descriptive works, because their distinguishing characters cannot be established. It is hoped that the following notes may stimulate the restudy of genotypes, wherever this is possible, but unless additional information is forthcoming in the meantime, it will not be possible to give these genera any consideration.

*Amblyceras* Glockner (1842, p. 30), established for forms "probably different from *Spirula*, with two rather distant whorls and a blunt end." The genotype, *A. rittbergense* Glockner, was neither described nor figured. The derivation of the specimen is given as Rittberg? in Moravia. It is probable that it came either from Silurian or Devonian strata.

*Apioceras* Fischer (MS.), published by Fahrenkohl (1844, p. 779). Fahrenkohl remarks that the same genus had been called *Gomphoceras* by Murchison and Münster, though neither of these authors ever used this name. Apparently, *Apioceras* was intended to replace *Gomphoceras* Sowerby (1839), but in 1933 (p. 40) Miller, Dunbar and Condra selected *Apioceras trochoides* Fahrenkohl (1844, 779) as the genotype. This species comes from the "Bergkalk" (Carboniferous) of Karowa, Russia, but its description and figure are quite insufficient and, as Miller, Dunbar and Condra have stated, "it will not be possible to refer any other species to the genus," nor is it possible to determine its systematic position.

*Bisiphytes* Montfort (1808, p. 55). Genotype: *B. reticulatus* Montfort (1808, pp. 55–56). Derivation: Sombrenon in Burgundy, France, evidently from strata of Jurassic age. Montfort was of the opinion that his type specimen possessed two siphuncles (hence derivation of name). Pia pointed out (1914, p. 43) that Montfort evidently mistook the internal lobe of the suture for a second siphuncle. Spath (1927, p. 21) selected *Nautilus striatus* Sowerby (1817) as genotype of *Bisiphytes*, but this action is not justified under the International Rules, as already indicated by Miller, Dunbar and Condra (1933, p. 43). As it is evidently impossible to recognize even the specific features of the genotype of *Bisiphytes*, no other species should be referred to that genus, whose exact systematic position will remain indeterminable.

*Coleoceras* Agassiz (1846), see *Koleoceras* Portlock (1843).

*Conoceras* Bronn (1837, p. 98) (= *Conoceratites* d'Archiac and de Verneuil, 1842). Genotype: *Conoceras angulosum* Bronn. Derivation: Island off Thessalon, Lake Huron. *Bathmoceras* Barrande (1865) was long thought to be a synonym of *Conoceras*, but in 1934 (p. 340) Ulrich and Foerste announced that the genus was an endoceroid, possibly related to *Cameroceras*. Until more observations on the type specimens are available, the position of *Conoceras* remains uncertain.

*Conoceratites* d'Archiac and de Verneuil (1842) was evidently used instead of *Conoceras* Bronn and should be regarded as a synonym of the latter.

*Cyrthocerus* King (1844, p. 274) was established for curved nautiloids; no species were mentioned in connection with this name. The name is, however, a homonym of *Cyrtocerus* Conrad (1838), which is a synonym of *Cyrtoceras* Conrad (1838). A renaming of King's "genus" seems to be unwarranted.

*Diaphragmoceras* Hyatt (1900, p. 514) was established for nautiloids whose siphuncle is divided by transverse tabulae. No species are mentioned in the original description nor have, as far as I am aware, any species ever been referred to this genus. No legal objection could be raised to the selection of any of the now quite numerous species generally referred to the "Diaphragmida" group as the genotype of *Diphragmoceras*. Since, however, Schuchert and Dunbar have stated (1934, p. 47) that Hyatt's original specimens of *Diaphragmoceras* came from a certain bed in the Lower

Ordovician St. George series of Newfoundland, it seems best, before taking any further action, to await the results of a restudy of these specimens.

*Changkiuoceras* Shimizu and Obata (1935, p. 3). The original description reads: "This genus is close to *Penhsioceras*, but with shorter, narrower, more acute endoconch" (sic!). The genotype *C. shantungense* is a *nomen nudum* and the exact affinities of the genus can, therefore, not be established.

*Diploceras* Conrad (1842, p. 267). Genotype: *D. vanuxemi* Conrad (1842, p. 267), from the Trenton limestone of Trenton Falls, New York. The genotype is evidently an endoceroid, and Whitfield (1882, p. 229) was inclined to regard it as conspecific with *Endoceras proteiforme*. If this is correct, *Endoceras* Hall (1847) would become a synonym of *Diploceras*. It is, however, very difficult to determine the relationships of *Diploceras vanuxemi* from the description given by Conrad and, for the time being, it seems more advisable to regard *Endoceras* as a valid generic name and *Diploceras* as a genus of indeterminate affinities.

*Discus* King (1844, p. 274). This name is invalidated by *Discus* Fitzinger (1833). In the opinion of its author it should comprise all coiled nautiloids, but it is thought inadvisable to rename this genus, since no species were originally referred to it and its description was given in a very general way. Also, it is possible that the genus can be regarded technically as a synonym of Ellipsolites Sowerby (not Ellipsolithes Montfort), which is an ammonoid.

*Euorthoceras* Foerste (1889, p. 278) Miller, Dunbar and Condra have already pointed out (1933, p. 49) that, when this generic, or rather subgeneric, name was first introduced, all the species mentioned in connection with this name were referred to that subgenus with reservation, and according to Art. 30e, none of them is eligible as the genotype. Moreover, no definition, diagnosis, or indication as to the characters of *Euorthoceras* was given in the original publication, and it is, therefore, not possible to say that a "genus" or "subgenus" *Euorthoceras* has been established in that year, and that name should be regarded as a *nomen nudum* as of that year. However, in 1893 (b, pp. 539–543) Foerste again used the name in connection with a number of species. *Euorthoceras* appears here as a subgenus of *Orthoceras* and three species were now referred to it unconditionally, viz. *Orthoceras* (*Euorthoceras*) *ignotum*, *O.* (*E.*) *erraticum*, and *O.* (*E.*) *hanoverense*. As it appears that *Euorthoceras* 1889 can have no status in nomenclature, it seems that that name must date from 1893 and that the genotype must be selected from among the species mentioned above. The two first mentioned species were discussed in more detail by Foerste in another publication in the same year (Foerste 1893 a), but the name *Euorthoceras* was not mentioned in that paper at all. The three species from which the genotype of *Euorthoceras* must be selected are rather different in structure, and it is most probable that they belong to three different genera. No action is, therefore, proposed in this connection, until additional information on these species has been forthcoming.

*Foersteoceras* Shimizu and Obata (1936, p. 21). Genotype: *Orthoceras selkirkense* Whiteaves (1892, p. 82) from the Ordovician Red River formation of Manitoba. The genus was established for orthocones with rather distant, coarse, prominent annulations. The name is preoccupied by *Foersteoceras* Ruedemann (1925). Since the finer surface ornamentation of *O. selkirkense* is not known, and the relative distance of the annulations cannot be regarded as a feature of generic importance, the exact relationships of this species will be difficult to establish, and it is probably unnecessary to rename the genus.

*Gomphoceras* Sowerby (1839, p. 620). Genotype: *G. pyriforme* Sowerby. Foerste has repeatedly emphasized (1930, p. 363; 1936, p. 79) that this genus cannot be regarded as well-established and that it might turn out to be synonymous with *Hexameroceras*, *Tetrameroceras* or *Mandaloceras*. At present it will not be possible to give a proper description of the genus or to refer it to any definite place in the system of nautiloids.

*Gyrocerus* King (1844, p. 274) was established for nautiloids which are "tendril-shaped or open-coiled." No species are mentioned in the original description, and as far as I am aware no species have ever been

used in connection with this generic name. It seems inadvisable to revive the name by assigning any species to it.

*Hortolus* Montfort (1808, p. 282). Genotype: *H. convolvans* Montfort. Many authors have regarded this name as a synonym of *Lituites* "Montfort." This is, however, quite impossible since the genotype of *Hortolus* came from the vicinity of Namur, Belgium, probably from strata of Devonian or Carboniferous age, whereas *Lituites* is an Ordovician genus. Montfort's figure, which indeed suggests a Lituites of the *perfectus* type, must be highly imaginative. Also, it cannot be decided whether or not Steininger (1833, p. 370) was correct in referring a gyroceraconic, exogastric specimen from the Devonian of the Eifel to *Hortolus convolvans*. Future research may make it possible to recognize the genus among Devonian or Carboniferous material from western Germany or Belgium, but at present it cannot be properly identified.

*Koleoceras* Portlock (1843, p. 378 = *Coleoceras* Agassiz, 1846). Three species were described from the "Silurian" of Ireland, but no genotype has apparently ever been selected. Portlock established the genus on specimens which seemed to show "external appendages" of the shell. He is careful in expressing an opinion on these "appendages" and it seems that his specimens were strongly crushed and flattened orthoconic forms in which part of the septa have been crushed and portions of the shell have become detached from the conch. It will probably never be possible to determine exactly the generic relationships of these fossils, and it is not possible to assign them to any place in our present system of nautiloids.

*Mollossus* Montfort (1808, p. 350) = *Orthoceratites* Gmelin, 1793.

*Nautilites* Pallas (1771, p. 478). Genotype: *N. complanatus* Pallas, from the Wolga region of Russia. This is the first time the name *Nautilites* has been used in print in a Linnean sense, and Lamarck's use of the same name in 1799 (p. 79) is thus invalidated. It is clear from his description that Pallas refers to a fossil nautiloid, but the description (no figure is given) is not sufficiently accurate to assign the genus to any particular group of nautiloids.

*Nelimenia* Castelnau (1843, p. 33). Genotype: *N. incognita* Castelnau, from Montmorency, Canada. The genotype is an unrecognizable breviconic conch resembling *Beloitoceras* or one of its many related genera. Unless it will be possible to study topotype material, the genus will remain unrecognizable.

*Nothoceras* Eichwald (1860, p. 1193). Genotype: *Orthoceras impressum* Eichwald (1857, p. 179), from the Lyckholm stage of Estonia. I have previously (1930, p. 271) ventured the guess that this genus might be synonymous with *Kochoceras* Troedsson, 1926. Description and figures of Eichwald's species are, however, so vague that this must be regarded as rather uncertain. The name is a homonym of *Nothoceras* Barrande (1856, p. 317) but it is inadvisable to replace it by another name before the type specimens have been found and restudied.

*Orthoceras* Deshayes (1831, p. 217). As has been pointed out by Teichert and Miller (1938) Deshayes was the first Linnean author to use the name *Orthoceras* in connection with a fossil nautiloid. His name is a homonym of *Orthoceras* Bruguière (1789), but since Deshayes' only species, *O. simplex*, is poorly defined and lacks distinguishing features, it is inadvisable to rename this fossil.

*Orthoceratites* Gmelin (1793, p. 412). Genotype: *Orthoceratites gracilis* Blumenbach (1803). This genus remains unrecognizable as pointed out by Teichert and Miller (1936, p. 357), and it will not be possible to refer any other species to it. Schindewolf, in 1933, referred to the genus several orthoconic nautiloids from the Devonian of Germany without, however, stating any particular reasons for doing so.

*Orthocerus* King (1844, p. 274). The name was used in a broad sense for all straight nautiloids. It seems never to have been used in connection with a specific name, and in the sense applied by King it covers the same variety of forms as *Orthoceros* Brünnich, 1771 (see Teichert and Miller, 1936). It is inadvisable to revive the name by referring any species to it.

*Sannionites* Fischer de Waldheim (1829 p. 325). Genotype: *Sannionites crepitaculum* Fischer de Waldheim (1837, p. 126). The genotype is an unrecognizable fragment of

an orthoconic conch with a subcentral siphuncle. Hyatt (1884, p. 266) regarded the genus as synonymous with *Cameroceras* Conrad, but this opinion is not tenable. The systematic position of the genus remains indeterminable.

*Spirulites* Parkinson (1811, p. 110). The genus is described in rather vague terms as resembling *Spirula*, but differing mainly in size. It is clear that the name is applied to fossil cephalopods, for the author writes: "The fossils shells of this genus have hitherto been named *Lituites* . . . but in these pages I shall denominate them *Spirulites*, in accordance with the name of the [living] genus. "He then continues to describe the characteristics of shells which are now usually known under the name of *Lituites*. No species were referred to the genus and it is, indeed, somewhat questionable whether Parkinson can be regarded as a Linnean author. *Spirulites* Parkinson can probably be regarded as a synonym of *Lituites*, the author of which seems to be Gmelin.

## MISCELLANEOUS NOMENCLATURAL PROBLEMS

In the diagnosis of *Campulites* Deshayes (1845, p. 253), the author says that he had announced this genus as early as in 1830. However, in his publication of that year (p. 226) he had used the French transcription "Campulite;" moreover, no description accompanied that name, so that the genus must date from 1845. In his description of the genus Deshayes states that later (after 1830) Goldfuss had characterized the genus in a new and more complete manner. The only nautiloid genus established by Goldfuss is *Cyrtoceratites* Goldfuss, 1830, and it seems evident that *Campulites* Deshayes is a synonym of that genus, although several later authors regarded it as a synonym of *Phragmoceras* Broderip.

*Cyrtoceratites* Goldfuss, in Hoeninghaus (1830 p. 228). As pointed out by me in 1939, this is the genus usually referred to as "*Cyrtoceras*" and credited to Goldfuss 1832 (in de la Beche's Handbuch der Geognosie), where, however, the name was spelled *Cyrtocera*. As the genotype of *Cyroceratites* I select *Cyrtoceratites depressus* Goldfuss, first mentioned by Hoeninghaus in 1830 and fully described and figured by Bronn (1837, p. 101). A more modern description of this species has been given by Foerste (1930, p. 290).

*Discoceras* Barrande (1867, p. 177). Genotype: *Clymenia antiquissima* Eichwald (1842, p. 33), from the Ordovician of Estonia and Norway. The genus was established in the same year as the ammonoid *Discoceras* Hyatt (1867, p. 76), which was later on suppressed as a homonym. The Director of the Museum of Comparative Zoology at Harvard College has kindly informed me that Hyatt's paper was published in December 1867. The preface to the first text volume of Barrande's Système Silurien (Cephalopods) bears the date of the 2nd February 1867. Even if that volume might not have appeared during the same month, it is reasonable to assume that it appeared prior to December, and that, therefore, Hyatt's choice of *Discoceras* does not invalidate Barrande's name.

*Romingoceras* was established by Foerste in 1933 (p. 129) with *Romingoceras josephianum* as genotype. The description of this species, however, is headed "*Romingeroceras josephianum*" on p. 130 of the same publication. Since Foerste stated that Rominger had collected the type specimen, preference should be given to the spelling adopted on p. 130 and *Romingoceras* should be suppressed in favor of *Romingeroceras*.

*Trundleoceras* Foerste (1938, p. 81) was used in connection with two species from the Upper Canadian of the Mingan Islands, Quebec, viz. *Piloceras canadense* Billings and *Trundleoceras coarctum*, Foerste. No generic description was given and no genotype selected. Strictly speaking, the name *Trundleoceras* is, therefore, not available under the International Rules. It is, however, evident that the two species mentioned above belong to the genus *Allopiloceras* Ulrich and Foerste (1936), and that the name *Trundleoceras* can be suppressed on account of synonymy.

*Monilifer* Fritsch (1906, p. 245). This name was established for Quenstedt's Triassic "group of *Nautilus bidorsatus*," though the author did not select a genotype. *Nautilus bidorsatus* Schlotheim is, therefore, here chosen and *Monilifer* Fritsch becomes an exact synonym of *Germanonautilus*

Mojsisovics (1902, p. 235), which has the same genotype. Both genera were listed separately by Schmidt (1928, p. 284).

GENERIC NAMES FOR NONEXISTENT FORMS

These are names of hypothetical genera which have no status under the Rules (compare Opinion 2 of the Intern. Comm. Zool. Nomencl.).

*Lituunculus* Barrande (1867, p. 177).

*Protovaginoceras* Ruedemann (1905, p. 326).

*Proteropiloceras* Ruedemann (1905, p. 330). Kobayashi, in 1937, erroneously regarded *Cassinoceras* Ulrich and Foerste, 1936 (genotype: *Piloceras explanator* Whitfield), as a synonym of *Proteropiloceras*. Ruedemann leaves no doubt that *Piloceras explanator* does not possess all the characteristics of that hypothetical genus.

DESIGNATIONS

In 1867, Barrande introduced a number of designations for certain groups of breviconic nautiloids with constricted and lobed apertures. He divided (p. 203) his species of *Phragmoceras* into two series, endogastric and exogastric forms, and each series into a number of groups according to the number of lobes recognizable in the aperture of the species. No special designation was attached to forms with an entire aperture ("orifice non lobé"); forms with two lobes were called Dimères, forms with four lobes Tetramères, with six lobes Hexamères, with eight lobes Octamères. Similarly, on pp. 264–265, the species of *Gomphoceras* were grouped in two series, exogastric and endogastric, and the series were subdivided into groups after the same principle, viz. the shape of the aperture. Again, no special designation was attached to forms with an entire aperture. Forms with two lobes were called Dimorion, forms with three lobes Trimorion, with four lobes Tetramorion, with five lobes Pentamorion, and with six lobes Hexamorion.

These names have been listed as generic names in recent zoological Nomenclators and it is, therefore, necessary to consider them briefly. Barrande had very definite ideas about the question: What constitutes a genus?, and he recognized but a limited number of the genera which had been established up to the time of his writings. In different parts of his "Système Silurien" he discussed all these genera in considerable detail, but nowhere does he refer to the above-mentioned names as genera as he would have them understood. It is, therefore, quite clear that he himself did not regard these designations as generic names, and that he had not intended to establish genera when he differentiated between those groups. As a matter of fact, such a procedure would have been contrary to the taxonomic principles to which Barrande adhered. Nowadays we do regard those groups as distinct genera, and if Barrande designations were to be regarded as valid generic names, they would invalidate such names as *Trimeroceras*, *Tetrameroceras*, *Pentameroceras*, and *Hexameroceras*, which were established by Hyatt and are now commonly in use. It seems however, that Barrande's designations must be regarded in the light of the principles laid down in Opinions 72 and 132 of the International Commission on Zoological Nomenclature. They are of the same kind as Herrera's designations, Rhumbler's formulae and Sobolew's "Gattungsbezeichnungen" and can have no status in nomenclature. They should not even be listed in Nomenclators.

REFERENCES

References to new genera (to and including the letter L) can be found in S. A. Neave's new "Nomenclator Zoologicus," vols. 1 and 2, London, 1939. The data given in this work have been checked by me and references to be found there are not listed below. In addition, Sherborn's "Index Animalium" and the "Nomenclator Animalium Generum et Subgenerum," edited by the Prussian Academy of Science, have been consulted.

BARRANDE, J., *1856*, Über die Unterscheidungsmerkmale der Nautiliden, Goniatitiden und Ammonitiden und über die neue Sippi *Nothoceras: Neues. Jahrb.*, pp. 308–325, pl. 3.

BECHE, H. T. DE LA, *1832*, *Handbuch der Geognosie*. Nach der zweiten Auflage des englischen Originals bearbeitet von H. T. von Dechen. Berlin, pp. xvi+612.

BRONN, H. G., *1837*, *Lethaea Geognostica*, oder Abbildungen und Beschreibungen der für die Gebirgsformationen bezeichnendsten Versteinerungen. 2. Aufl. Bd. 1. Stuttgart, pp. 1–768.

CASTELNAU, F. DE, *1843*, Essai sur le système

silurien de l'Amérique septentrionale. Inst. de France: *Acad. royale sci.* Paris, Stuttgart.

DESHAYES, G. P., *1830*, Histoire naturelle des vers. Par Bruguière et de Lamarck. Continuée par M. G. P. Deshayes. *Encyclopédie méthodique*. vol. 2. Paris, pp. vii+594.

——, *1831*, *Déscription des coquilles caractéristiques des terrains*. Paris, pp. 1–257, pls. 1–14.

DESHAYES, G. P., et MILNE-EDWARDS, H., *1845*, *Histoire naturelle des animaux sans vertèbres*. Par J. B. P. A. Lamarck. 2nd ed., vol. 11. Paris, 665 pp.

EICHWALD, E., *1842*, *Die Urwelt Russlands:* 2. Heft. Beitr. z. Kenntn. d. Russ. Reiches, herausgeg. v. K. E. v. Baer. St. Petersburg.

——, *1851*, Naturhistorische Bemerkungen, als Beitrag zu einer vergleichenden Geognosie, auf einer Reise durch die Eifel, Tyrol, Italien, Sizilien und Algier: *Soc. Naturalistes, Moscou, Nouvelles Mém.*, t. 9, Moscow, 464 pp., 4 pls.

——, *1857*. Beitrag zur geographischen Verbreitung der fossilen Thiere Russlands. Alte Periode: *Soc. Naturalistes, Moscou, Bull.*, vol. 30, no. 1, pp. 192–212. Moscow.

——, *1860*, *Lethaea Rossica ou Paléontologie de Russie*. T. 1, 2nd sec., pp. 681–1657. Stuttgart.

FAHRENKOHL, A., *1844*, Bemerkungen über einige Fossilien der Moskowischen und Kalugaischen Gouvernements: *Soc. Naturalistes, Moscou, Bull.*, vol. 17, pp. 779–781. Moscow.

FISCHER DE WALDHEIM, G., *1829*, Sur les céphalopods de Moscou et de ses environs: *Soc. Naturalistes, Moscou, Bull.*, vol. 1, pp. 314–333. Moscou.

——, *1830–1837*, *Oryctographie du Gouvernement de Moscou*. Moscow.

FOERSTE, A., *1889*, Notes on Clinton group of fossils, with Special Reference to collections from Indiana, Tennessee, and Georgia: *Boston Soc. Nat. History*, Proc., vol. 24, pp. 263–355, pls. 5–9.

——, 1893a, Remarks on specific characters in *Orthoceras: Am. Geologist*, vol. 12, pp. 232–236.

——, *1893b*, Fossils of the Clinton Group in Ohio and Indiana: *Ohio Geol. Survey Rept., Paleontology*, vol. 7, pp. 516–601. Norwalk, Ohio.

——, *1917*, Notes on Richmond and related fossils: *Cincinnati Soc. Nat. History, Jour.*, vol. 22, pp. 42–55, 3 pls.

——, *1930*, Three studies of cephalopods: *Denison Univ., Sci. Lab. Bull.*, vol. 24 (1929), pp. 265–381, pls. 41–63.

——, 1933, Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario, Part II: *Denison Univ., Sci. Lab. Bull.*, vol. 28, pp. 1–146.

——, *1936*, Silurian cephalopods of the Port Daniel area on Gaspé Peninsula, in Eastern Canada: *Denison Univ., Sci. Lab. Bull.*, vol. 31, pp. 21–92, pls. 4–26.

——, *1938*, Cephalopoda. In W. H. Twenhofel, Geology and Paleontology of the Mingan Islands, Quebec: *Geol. Soc. America, Spec. Pap.* no. 11, pp. 76–105, pls. 12–24.

FRITSCH, K. VON, *1906*, Beitrag zur Kenntnis der Tierwelt der deutschen Trias. *Naturf. Gesell. Halle, Abh.*, Band 24, pp. 219–285, 10 pls.

GMELIN, J. E., *1793*, *C. a Linnaeus, Systema naturae*, 13th ed., 3, Lipsiae.

KING, W., *1844*, An attempt to classify the Tetrabranchiate Cephalopods: *Annals and Mag. Nat. History*, ser. 2, vol. 14, pp. 271–279.

KOBAYASHI, T., *1937*, Contribution to the study of the apical end of the Ordovician nautiloid: *Japanese Jour. Geology and Geography*, vol. 14, pp. 1–21, pls. 1–2.

LAMARCK, J. P., *1799*, Prodrome d'une nouvelle classification des coquilles. *Soc. Histoire Nat. Paris, Mém.*, (an 7).

MEEK, F. B., *1871*, Descriptions of new species of invertebrate fossils from the Carboniferous and Devonian Rocks of Ohio: *Acad. Nat. Sci. Philadelphia, Proc.*, pp. 57–93.

MILLER, A. K., DUNBAR, C. O., and CONDRA, G. E., *1933*, The nautiloid cephalopods of the Pennsylvania system in the Mid-Continent region: *Nebraska Geol. Survey*, Bull. 9, 2nd ser., pp. 11–236, pls. 1–24.

PALLAS, P. S., *1771*, *Reise durch verschiedene Provinzen des Russischen Reiches*, 1. Theil. St. Petersburg.

PARKINSON, J., *1811*, *Organic remains of a former world*, vol. III. London, pp. xvi+479, 22 pls.

PIA, J. VON, *1914*, Untersuchungen über die liassischen Nautiloidea: *Beitr. Geol. Palaeont. Oesterr Ung. u. Orients*, vol. 27, pp. 19–86, pls. 4–10.

RUEDEMANN, R., *1905*, The structure of some primitive cephalopods: *New York State Mus., Bull.* 80 (Paleont. 10), pp. 296–341, pls. 6–13.

SCHINDEWOLF, O. H., *1933*, Vergleichende Morphologie und Phylogenie der Anfangskammern tetrabranchiater Cephalopoden: *Preuss. geol. Landesanstalt, Abh.*, neue Folge, Heft 148, 115 pp., 4 pls.

SCHMIDT, M., *1928*, *Die Lebewelt unserer Trias*. Öhringen, 461 pp.

SCHUCHERT, CHARLES and DUNBAR, C. O., *1934*, Stratigraphy of Western Newfoundland: *Geol. Soc. America, Mem.* 1, 123 pp., 11 pls.

SHIMIZU, S., and OBATA, T., *1935*, New genera of Gotlandian and Ordovician nautiloids: *Shanghai Sci. Inst., Jour.*, sec. II, vol. 2, pp. pp. 1–10.

——, *1936*, On some new genera of Ordovician nautiloids from East Asia: *idem.*, vol. 2, pp. 11–25.

SOWERBY, J. DE C., *1839*. Fossil Shells of the lower Ludlow age: In R. C. Murchison, *The Silurian system*, Part II. London.

SPATH, L. F., *1927*, Revision of the Jurassic cephalopod fauna of Kacch (Cutch): *Palaeontologia Indica*, n.s., vol. IX, no. 2, pp. 1–71, pls. 1–7.

STEININGER, J., *1833*, Observations sur les fossiles du calcaire intermédiaire de l'Eifel: *Soc. géol. France, Mém.*, vol. 1, Paris.

TEICHERT, C., *1930*. Die Cephalopoden-Fauna

der Lyckholm-Stufe des Ostbaltikums: *Palaeont. Zeitschr.*, vol. 12, pp. 264–312, pls. 5–9.

——, and MILLER, A. K., *1936*. What is *Orthoceras?*: *Am. Jour. Sci.*, vol. 31, pp. 352–362.

——, *1938*, The earliest use of the name *Orthoceras* for cephalopods: *Am. Jour. Sci.*, vol. 35, pp. 143–144.

ULRICH, E. O., and FOERSTE, A. F., *1934*, Notes on the schistochoanites: *Geol. Soc. America, Abstr. Proc.*, pp. 339–340.

——, *1936*, New genera of Ozarkian and Canadian cephalopods: *Denison Univ. Sci. Lab., Bull.*, vol. 30, pp. 259–290, pl. 38.

WHITEAVES, J. F., *1892*, The Orthoceratidae of the Trenton limestone of the Winnipeg Basin: *Royal Soc. Canada, Trans.*, vol. 9, sec. 4, pp. 77–90.

WHITFIELD, R. P., *1882*, Paleontology: *Wisconsin Geol. Survey of 1873–1879*, vol. 4, pp. 163–364.

MANUSCRIPT RECEIVED BY THE EDITOR APRIL 23, 1940.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 6, PP. 598–602, 3 TEXT FIGS., NOVEMBER, 1940

# DIAGRAMMATIC REPRESENTATION OF AMMONOID SUTURES

W. M. FURNISH AND A. G. UNKLESBAY
Oklahoma A. and M. College, Stillwater, Oklahoma, and State University of Iowa, Iowa City, Iowa

ABSTRACT—Various methods of drawing sutures are reviewed, and a procedure involving the use of a camera lucida is illustrated and described in detail.

THE SUTURES of ammonoids are used more than any other feature in the classification of this group of fossils. Although the gross outline is sufficient in most cases for identification, the trend toward finer biologic subdivision makes it increasingly essential that true proportion and detail be represented in suture drawings. The general principles used in preparing such diagrams are readily understood; however, the technique of actual application involves numerous problems.

## METHODS PREVIOUSLY DESCRIBED

Several articles have appeared describing devices and methods to be used in drawing representations of ammonoid sutures. The major distinction to be made in the various methods is that some involve a direct contact with the suture during transfer and the others employ only projection. The transfer of a suture from the surface of an expanding coil to a plane necessarily causes certain distortions. However, any method which is practiced carefully, except possibly free-hand drawing, will produce a consistent kind and amount of error. Therefore the value of the illustration is not greatly affected. In any case, there is ample reason to believe that diagrammatic representations of sutures can be satisfactorily accomplished by any one of several means, and that the most practical method in any given case will be determined primarily by the size and preservation of the material involved and the facilities available. In addition to the methods discussed here, there may be numerous others that have been employed; it is not likely, however, that they differ greatly in mode of application.

Probably the simplest means by which sutural representation is accomplished is that outlined in some detail by Bassé (1930) and by Elias (1933). This consists of the application of a strip of cellophane or some other thin transparent flexible medium to the surface of the shell and covering the suture intended for reproduction. If the cellophane is held securely in position with one hand, the other is free to follow the suture with a pen or stylus. Merely indenting the surface of the cellophane, as suggested by Bassé, makes an exact line, but the cellophane may be inked directly if greater contrast is desired. The copy can then be projected or photographed for enlargement to desired size; a pantograph adapts itself readily for the same purpose. Bassé states that as early as 1921, C. P. Nicolesco had practiced a similar method, in which collodion was applied directly to the specimen. The inside of the "peel" obtained, then showed the sutures in relief in cases where the suture lines had existed as depressions on the internal mold of the shell. The same method can be employed on smooth whorls, for if the sutures are visible through the collodion, they may be traced directly with ink.

Sutures which are relatively simple can be drafted from direct measurements. The easiest way to apply this method is by the use of an ocular grid and corresponding graph paper—a combination often employed in similar illustrative drawing. It is usually advisable in this case to draw a transverse "base line" from the venter of the specimen to the umbilicus approximately bisecting midheight of lobes and saddles. Points of control can then be plotted with reference to a corresponding line on the drawing paper. On larger speci-

mens, direct transfer of points can be made with simple dividers, or proportionate dividers may be used to facilitate the construction of an enlarged drawing. This method involves a considerable amount of uncertainty and is somewhat laborious for anyone possessing only a fair aptitude for representing proportion.

A direct application of the principle of the pantograph in the representation of suture diagrams has an obvious appeal and is a logical answer to some of the problems involved. The apparatus described by Lupher, Lupher, and Packard (1930) seems to surmount the mechanical difficulties concerned with its use. The major objection to the universal adoption of this method, is the complexity of the device, which must be carefully constructed if sufficient accuracy is to be obtained. It may be expected that the margin of error is determined primarily by the operator's ability to follow sutures with the "tracing stylus," an important factor in specimens of no more than moderate size. Enlargement involves an additional step in the procedure.

After some experimentation, it was concluded that the procedure described by Böse (1907) constituted the most practical method for reproducing ammonoid sutures. Although certain modifications were adopted, the same general outline was retained. As described by Böse, the main feature is a device by which the specimen may be rotated upon an axis passing through the center of curvature of the transverse periphery of the whorl and parallel to the plane of the coil. Successive views of portions of the suture during rotation are recorded by photography. Each view is overlapped by adjacent ones enough to remove essentially all distortion due to fore-shortening. In actual practice, the authors have found that the utilization of a camera lucida, instead of a camera, simplifies and accelerates the procedure somewhat. Elias (1933, p. 293) discusses the use of a microscope and camera lucida in a similar manner. A wide range of magnifications can be obtained by using various simple lenses and the combinations available in a compound microscope. Although the distance from ocular to drawing field is usually established equal to that from the ocular to the visual image of the suture, magnifications may be adjusted, within limits, by changing the ratio of these distances. In adapting Böse's device for a camera lucida, the axis of rotation was altered from vertical to horizontal. Under the latter circumstance, a "moving shelf" similar to that of Lupher, Lupher, and Packard was found to be most satisfactory.

## RECOMMENDED PROCEDURE

The procedure outlined here now seems to be the most readily adaptable to various conditions of size, preservation, and complexity of suture. While, individually, the basic principles involved are in no sense original with the authors, the integration of these fundamentals into what they regard as a more practicable method is the result of experience with hundreds of specimens. Also, the writers are indebted to Dr. A. K. Miller for helpful suggestions.

The general view (text fig. 1) shows a low magnification or macroscopic arrangement in which an Abbe type camera lucida is held in position by a fixed upright and only a simple lens is used. A combination of this general type of drawing apparatus and movable stage is provided as standard apparatus by several optical supply houses. The only piece of special equipment necessary is a simply constructed moving shelf (text fig. 2). A compound microscope may be substituted directly, if greater magnification is desired.

The periphery of the whorl in most shells deviates considerably from the arc of a circle. Therefore the center of curvature is not a point but a line and rotation of the specimen on any one axis alters its vertical and lateral position. Adjustments must then be made to return the desired segment of the suture to a median position in the field of the camera lucida and to a height nearly the same as used for the previous view. Any appreciable difference in height causes a change in the distance from ocular to specimen and results in a different scale of magnification. The vertical adjustment can, in many cases, easily be accomplished by merely bringing the specimen into sharp focus. However, if the depth of focus is relatively great, a more nearly precise regulation is necessary. A folding or rotating "pointer" which can be brought into posi-

tion to check the height serves this purpose. Böse used a string between uprights to determine the position; the string was drawn taut when desired but was otherwise unobtrusive. A pointer device is often more convenient than the string, particularly for internal sutures, and is supported by a single movable upright rather than two which are fixed. Ordinary rack-and-pinion devices are advantageous for vertical and lateral adjustment of the specimen, but simpler arrangements are quite satisfactory.

beneath. A light-colored or white stylus is chosen which contrasts well with the two fields of view; a flattened side on the point of the stylus can be used to reflect light and accentuate this contrast. Also, the drawing field may be illuminated by a light source nearly on the same level as the paper; this results in a relatively small amount being reflected except from the stylus which is clearly visible.[1]

The specimen may be prepared in various ways to make the sutures more readily dis-

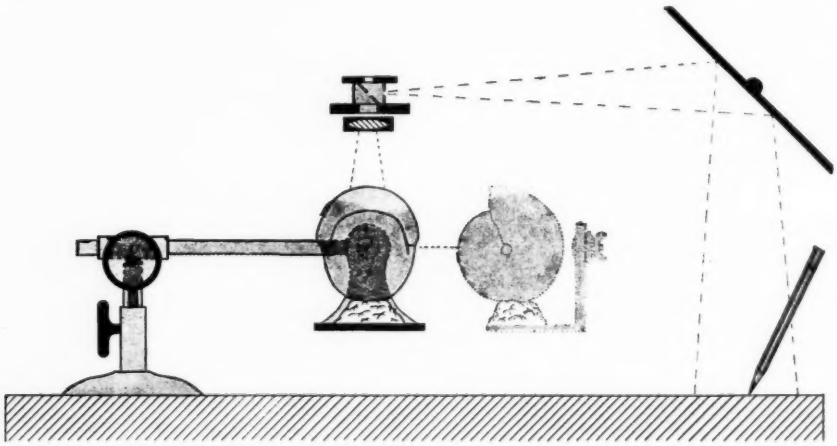


FIG. 1.—General view of suture-drawing apparatus.

A major difficulty encountered in the use of a camera lucida is the discrepancy in effective illumination on the specimen and on the drawing field. The amount of light upon the suture is reduced, in effect, proportionately to the square of the magnification in diameters. It is possible, however, to compensate for the difference even in cases where considerable magnification is desired. A brilliant spot light which can be focused on the specimen helps considerably. Also the camera lucida is usually provided with smoked discs of varying density which can be used to reduce the amount of light from the drawing field. In practice we have found that it assists greatly to use a dark sheet of paper on the drawing field rather than a white one. Carbon paper over drawing paper gives a dark field and at the same time the single operation provides a clear copy as a carbon tracing on the white sheet

cernible. After all of the surrounding matrix and shell material has been removed, details of the sutures may be made perceptible through very slight etching with dilute acid. Glycerin or any of various oils are used to temporarily clear the surface of "grain." In internal molds, sutures commonly exist as linear depressions. The contrast and general tone of the specimen may then be heightened by coating with ammonium chloride sublimate or a similar white powder supplied by the combustion of magnesium "ribbon." As mentioned by Böse and by Elias, painting the suture directly on the specimen generally more than compensates

[1] Recently the authors have employed an illuminated stylus on a completely darkened drawing field. This apparatus consists of a pointed glass rod attached to a very small pocket flashlight. The stylus is better defined if the point is slightly frosted and the remainder is covered with an opaque substance.

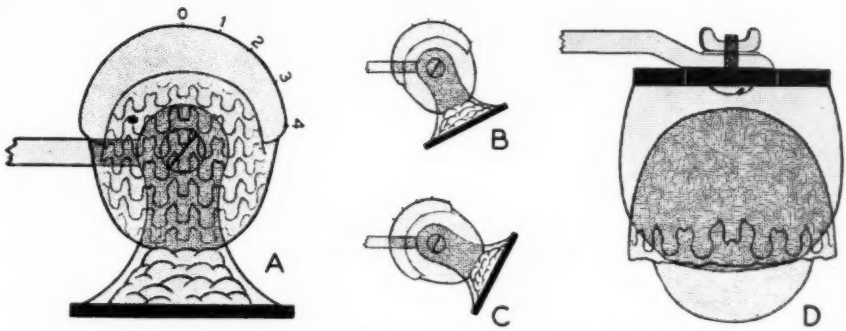



FIG. 2.—Detailed views of specimen mounted on turning shelf.

for the additional trouble involved. One side of the line is covered solidly with color applied with a fine camel hair brush. White water-color (China white) shows quite clearly on even light-colored specimens and can be readily altered or removed.

It is perhaps unnecessary to point out that, to avoid distortion, the mirror of the Abbe camera lucida is ordinarily set at 45°. If mounted on a binocular microscope, the mirror angle should be less, by one-half the angle which the ocular deviates from the vertical in a lateral direction. If an inclined ocular is employed, the drawing field must be supported on a platform of the same degree of inclination.

In text figure 2A, an anterior view of the turning shelf, the specimen is shown mounted in modeling clay so as to place the axis of rotation near the center of curvature for the periphery. In this position, the undistorted portion of the suture lies within points 0 and 1. The specimen is then rotated successively to the positions shown in text figures 2B and 2C while units of the suture are transferred in each case. Text figure 2D illustrates a view of the turning shelf from above, with the specimen and selected suture in proper position.

A complete suture may be drawn as a unit in a single operation if sufficient care is used. However, it is usually more convenient to construct elements of the suture and later combine them by tracing. In text figure 3A, the component parts of an external suture consisting of four units are shown. The dashed lines represent the portions of the field of view which have been distorted by fore-shortening. The segments shown in figure 3A are then aligned and overlapped by tracing to form the single figure shown in 3B. The dashed lines are, of course, not retained on the finished drawing. Numbers on the sutures in text figure 3 correspond directly to those on text figure 2A where the corresponding positions on the specimen are indicated.

Specimens of odd size and shape offer

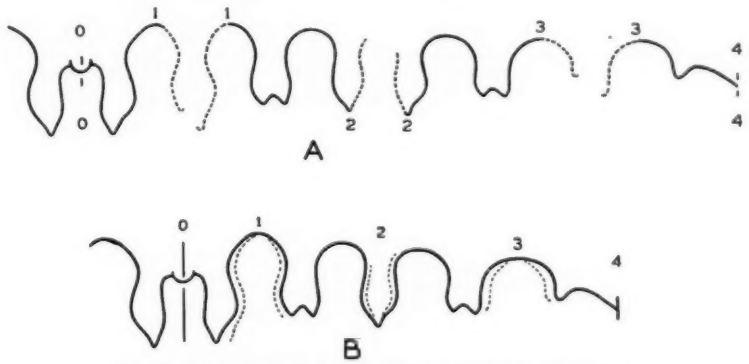



FIG. 3.—Unassembled segments and completed suture.

some difficulties in the preparation of suture drawings. Large specimens make it advisable to substitute a more spacious turning shelf for that found convenient in average cases. Thinly discoidal or lenticular specimens have sides so strongly flattened that it is not desirable to place the axis of rotation at the center of curvature. However, sutures are easily transferred from a surface with such a small amount of curvature with but little adjustment and no appreciable distortion. Internal sutures may be treated like external ones; in most cases, the specimen must be reset after viewing the exterior. The only additional difficulty is that a direct sight normal to the surface of the shell may be obscured by the specimen itself.

Sutures of nautiloids never reach more than a slight degree of complexity, but they can be reproduced diagrammatically by the same means as used for ammonoids. The nautiloid septa are, in most cases, simple concave discs with no additional flexures. The sutures rarely need to be illustrated diagrammatically, for they are to a large extent merely an expression of the shape of the whorls.

A suture drawing, in final form, may represent only a diagram of a single suture, it may comprise a partial reconstruction of one, or a composite of several. In the latter two cases, an attempt is made to illustrate the true form of a specific individual, but not necessarily the species. Interpretation is not as likely to influence the drawing if all the data is derived from a single source. However, successive sutures are essentially similar except for ontogenetic changes, which are rather gradual. Therefore, it is only reasonable to fill in missing portions of sutures and to check details from other parts of the whorl which has the desired part better exposed. Careful interpolation can logically be regarded as authentic. Likewise, the sutures on opposite sides, though in reverse, closely simulate one another. If proper care is used, reconstructions may thus be based upon two sides of a specimen. It should be noted, however, that in right and left sutures appreciable differences in secondary elements of the suture are not rare, and tertiary elements may be expected to differ considerably. Even greater danger of error is involved in cases where more than one specimen is used as the source of data; such a practice should probably be limited to a mere check of observations.

In addition to the magnification of a suture drawing, it is advisable to give at least one significant dimension of the conch. Unless there is a precise indication of the size of the specimen represented, it may be difficult to compare sutures of closely related species.

## BIBLIOGRAPHY


BASSÉ, E., *1930*, Procédé simple permettant de reproduire les cloisons d'Ammonites et de Nautiles: *Soc. géol. France, Bull.*, vol. 30, pp. 269–271.

BÖSE, EMIL, *1907*, Ein verbesserter Apparat zur photographischen Reproduktion von Ammonitensuturen und Ambulakren von Seeigeln: *Centralbl. Mineralogie, Jahrg. 1907*, pp. 422–429.

——, *1919*, The Permo-Carboniferous ammonoids of the Glass Mountains, west Texas, and their stratigraphical significance: *Texas Univ., Bull. 1762*, p. 8.

ELIAS, M. K., *1933*, Cephalopods of the Pierre formation of Wallace County, Kansas: *Kansas Univ., Sci. Bull.*, vol. 21, pp. 290, 293.

——, *1938*, Studies of Late Paleozoic ammonoids I. Methods of drawing sutures; bibliography: *Jour. Paleontology*, vol. 12, pp. 87–89.

LUPHER, A. W., LUPHER, R. L., and PACKARD, E. L., *1930*, An apparatus for the reproduction of suture-lines of ammonites: *Jour. Paleontology*, vol. 4, pp. 22–23.

MILLER, A. K., and FURNISH, W. M., *1940*, Permian ammonoids of the Guadalupe Mountain region and adjacent areas: *Geol. Soc. Am., Spec. Paper 26*, p. 4.


MANUSCRIPT RECEIVED BY THE EDITOR JULY 23, 1940.

# REVIEWS

FORAMINIFERA, THEIR CLASSIFICATION AND ECONOMIC USE, by Joseph A. Cushman Third edition, revised and enlarged, with an illustrated key to the genera, pp. 535 +viii, pls. 79, 14 charts, maps, etc., inserted as figures in text (not numbered serially), bibliography. Harvard University Press, Cambridge, Mass., April, 1940. Price $6.00.

This useful, handsome book is a somewhat enlarged and revised edition of the one reviewed by Moore in this Journal (vol. 7, pp. 446–447, 1933). The main purpose of the volume is to present a systematic catalogue of the genera of the Foraminifera arranged according to the author's views on genetic relationships. The catalogue (pp. 62–333) as presented is a noteworthy contribution to science because it assembles in one place many widely disseminated data. Students and specialists alike will be grateful for such a comprehensive compilation, where they find under each genus a designation of the genotype, an appropriate bibliographic citation or citations, a brief description, a statement of geological range, and sometimes an indication of geographic occurrence. Carl O. Dunbar is the author of the chapter dealing with the Fusulinidae. T. Wayland Vaughan and W. Storrs Cole are the authors of the part on the Orbitoididae, Discocyclinidae, and Miogypsinidae.

The workmanship is of superior quality. The book is well bound in brick-red cloth with gold lettering. The exterior size is $6\frac{3}{8} \times 9\frac{3}{8}$ inches (165 × 238 mm.). The 31 text plates are line drawings on white; the 48 excellent key plates are black-back-ground halftones printed on both sides of the page. The catalogue part of the book is attractive; the sequence of heads is clear. The flush-and-hang style in the 58 pages of topically-arranged bibliography is an aid to quick finding.

Thalmann (Eclogae geol. Helvetiae, vol. 31, no. 2, 1938 [1939] pp. 342–344) recently estimated that between the years 1826 and 1932 about 1100 genera and 9000 species of Foraminifera were named; during the seven years from 1931 to 1937, a new species was named every day. Cushman accepts 645 generic and subgeneric names as valid. It is thus easy to see that it was an enormous task to prepare a catalogue of the genera of Foraminifera with their synonyms. That a few names have escaped attention is no reflection on the author, as he will undoubtedly deal with them in the next edition. The following are among the names not treated in the present edition:

*Borelia*, *Checchiaites*, *Cibicidoides*, *Conomiogypsinoides*, *Cribropullenia*, *Cristellariopsis*, *Haplophragmella*, *Heliocyclina*, *Helicolepininoides*, *Helicostegina*, *Katacycloclypeus*, *Laevipeneroplis*, *Marginulinopsis*, *Nannoconus*, *Orbitolinopsis*, *Radiocycloclypeus*, *Vaculispira*, and *Vaginulinopsis*.

Chapters I to X (pp. 1–61) are little changed from the previous edition; they deal with generalities, such as the living animal, the test, and geologic distribution. These chapters are much condensed, and of course, their scope reflects the author's opinion of the relative importance of the subject matter. Many readers will hold the view that this minor part of the book might have been subjected to somewhat different treatment. For example, it is unfortunate that lack of space prevented a digest of such papers as those by Myers (1936, 1938), Natland (1933), Norton (1930) and Kleinpell (1938).

Since the title of the book leads the purchaser to believe that he will find an adequate discussion of the economic use of Foraminifera, it was disappointing to discover that only five pages (37–41) comprise the chapter on this subject. The chart on page 40 is misleading, as Zones cannot be subdivisions of "Sections" and "Divisions." Zones are time-stratigraphic units; they are subdivisions of Stages. Zones are thicknesses of strata delimited by paleontological criteria. Stages are units of a higher rank.

The fascinating subject of geographic distribution is dealt with in chapter VI. Recent studies on the west coast of North America (Martin and Keen, Proc. Geol. Soc. Am. for 1936 [1937] p. 384) have shown that warm-water faunas occur as far north as Lower California. The map on page 45, therefore, is not quite correct in all details.

The geologic distribution (pp. 47–51) of the Foraminifera, Cushman paints with a broad brush. Whether the ancestral foraminifer was naked, chitinous, arenaceous, or calcareous is relatively unimportant; the significant fact is that by Cambrian time —and probably long before—the Foraminifera were differentiated from other organisms not only as Foraminifera but also as several kinds of Foraminifera. This chapter might have been of more practical value if it had incorporated a tabulation such as that published by Chapman and Parr (Proc. Roy. Soc. Victoria, vol. 49, pt. 1, 1936). The interesting graphic analysis by Thalmann (op. cit., p. 340) would have been an instructive addition. The chart by Brotzen (Geol. Fören. Förhandl. 1936, p. 120) shows the "flourishing periods" of a number of families; such a graph offers intriguing possibilities.

A diagram (p. 62) shows the relationships of the families. The ancestral family is the Allogromiidae, whence sprang directly the Rhizammidae and Saccamminidae, with an early offshoot to the Astrorhizidae. The main phylogenetic trend is to the Ammodiscidae, from which radicle all the other families are derived. The Discocyclinidae and Miogypsinidae are not included in the illustration. The chief value of the chart is that it clearly expresses the author's views on relationships. The reviewer wonders if it would have been helpful also to represent graphically the views of other authors on the same subject, as differences of opinion frequently enliven a study and show students where they may offer valuable contributions. Suppose Cushman had accepted, as do many specialists, the family Bolivinitidae, had rejected *Cycloclypeus* from the family Camerinidae, and had arranged the Orbitolinidae according to Galloway (Manual of the Foraminifera). Suppose Cushman more frequently based his concepts of genera upon genotypes. If such suppositions were made, a radically different chart might result, and a student would understand clearly that any classification into genera and families is subjective.

The key (pp. 397–425) is not dichotomous and hence difficult for the student to use. The requirements of satisfactory keys are listed by Simon (Geol. Soc. Am. Proc., for 1936 [1937] p. 385). In order to get independent opinions concerning the workability of Cushman's key, the reviewer canvassed a considerable number of teachers, students, and economic paleontologists. The responses were unanimous: the key could be made much more useful.

No book of such a wide scope as this could be entirely free from minor imperfections. No mention is made of the careful study of *Loftusia* by Cox (Eclogae geol. Helvetiae, vol. 30, no. 2, 1937 [1938] pp. 431–449), who gives a description and phylogenetic derivation of the genus superior to that appearing on page 156 of the book. Tan's (1932) detailed analysis of *Cyclolypeus* is not mentioned. The genus *Nummulostegina* is placed in two families, the Fusulinidae (p. 138) and the Camerinidae (p. 217). The statement on pp. 50–51 concerning the "charts showing the geologic distribution of the Ammodiscidae, Valvulinidae, and Polymorphinidae" is only one-third correct. In most of the catalogue, the families and subfamilies are not given their author's names. Vaughan and Cole incorrectly accredit themselves with the authorship of the family name Miogypsinidae; this name was introduced by Tan (1936) and used in proper Latin form by Thalmann (1939) and Ovey (Proc. Geol. Assoc. vol. 49 [1938] p. 167, footnote). Galloway (1933) has stated that the correct transliteration from the Greek is *Actinocyclina*, not *Aktinocyclina*. Moore, in his review of the previous edition, called attention to incorrect computations of magnifications; many are still incorrect and no magnifications are given on plate 44 and elsewhere. For instance, key plate 1, figure 16, is from Brady (pl. 26, fig. 18), whose figure is of a specimen 0.86 mm. in diameter. Cushman's statement of magnification would make this same specimen 1.08 mm. in diameter. This would be a trivial matter if it were an isolated example and if statements of size were incorporated in the catalogue.

The study of the Foraminifera has now reached such a degree of specialization and complexity that it is impossible for any scientist, even the most gifted with ability, time for research, and facilities, to master the entire field. Appreciative of this fact, readers of this book will respect Cush-

man for his courage in preparing this indispensable work and will join the reviewer in congratulating him for it.

HUBERT G. SCHENCK

THE DEVONIAN OF PENNSYLVANIA: MIDDLE AND UPPER DEVONIAN by Bradford Willard; KEYSER LIMESTONE AND HELDERBERG GROUP by Frank M. Swartz; ORISKANY GROUP by Arthur B. Cleaves. *Pennsylvania Geol. Survey*, fourth series, Bull. G 19 (1939). 481 pp., 32 collotype plates, 95 text figs.

With the publication of this long-needed volume by the Pennsylvania Geological Survey, a new era in official stratigraphy is opened. Stratigraphers will be grateful to the authors, and especially to the Commonwealth for having produced a useful, modern report on the great Devonian sequence of Pennsylvania. The Devonian of Pennsylvania and New York State is probably the best representation of the system in the country, and one of the best in the world. This work belatedly establishes the key importance of Pennsylvania in the solution of many fundamental Devonian problems. Undoubtedly the three authors have the broadest grasp yet attained of the Lower and Middle Devonian history of the state.

The volume synthesizes the results of much work under official subsidy which the authors have prosecuted over a little more than a decade. Apparently because of the more exhaustive treatment given the Lower Devonian in original publications and the more general availability of these works, the major attention in the present volume is focused on the less known and less compactly reported Middle Devonian. The discussion of the Upper Devonian is somewhat cursory, and consequently the least satisfactory part of the report. Effort has been expended to keep the work within convenient bounds. Omissions and elisions result. Many problems remain unsolved. It is a report of progress rather than the definitive study of the system in Pennsylvania.

To the small group of stratigraphers and paleontologists who during the last fifteen years have been engaged in a restudy of the Devonian history of the Penn-York Embayment, this compendium means victory for the facieological concepts they have been urging on a reluctant official world. Here the state of Pennsylvania acknowledges the fundamental importance of facies studies and facies interpretations in unravelling the snarled stratigraphy of the Middle and Upper Devonian. Other surveys and especially textbook compilers will do well to note that for the Penn-York Embayment the era of "parallelism of strata" is over. Willard's work shows that Pennsylvania is one of the best places in the world for the study of facies phenomena. Beside this victory, differences of opinion, interpretation, and even of reporting, between stratigraphers and paleontologists who have studied the Devonian of Pennsylvania, are inconsequential. As more facts accumulate these disparities and resulting nomenclatorial snarls will disappear.

The usual telling charts, diagrams and half-tones of the Pennsylvania Survey reports are present. Poor reproduction unfortunately mars several of the half-tones. Facies maps and more formation maps would have been most welcome. The text shows evidence of careless editing; misspellings, repetitions and contradictions occur.

An innovation of great significance is the inclusion of 32 collotype plates of fossils. Aside from the publication long ago of Lesley's amazing Dictionary of Fossils, this is one of the first indications of paleozoological interest in the long history of Pennsylvania's Surveys. The plates have been prepared as stratigraphic indices and are generally useful in this capacity. Their greatest value is as documentary evidence of the materials used in compiling the accompanying faunal lists and charts. They serve also as a sample check for the paleontologist to evaluate the generic and specific determinations on which so much of the Devonian stratigraphy of the state depends. Possibly it is significant that some of the illustrated specimens, which appear to be inadequate for determination, carry specific names.[1]

[1] Plate 23 is an example of unconsidered determinations. This plate of Middle and Upper Devonian Pelecypoda illustrates 17 fossil fragments all of which carry generic and specific determinations on the plate description. Three of the specific determinations carry question marks. This reviewer, after several years special study of Devonian Pelecypoda, would not venture generic

Much better material could have easily been obtained from several of the horizons, such as the Oriskany and Chemung. It is confusing to find fossils from many horizons intermingled on one plate, and no constant scale of enlargement used. Some of the admixtures are misleading.[2] The photographs are occasionally inadequate; restorations and analytical lines are almost uniformly misleading. These critical remarks are not applicable to the Keyser and Helderberg plates, and Oriskanian ostracode illustrations, all of which are eminently satisfactory guides to the stratigraphy. The careful student of the volume will wish that ecological data had been given for the illustrated Middle and Upper Devonian faunas in view of the importance of facieology in this restudy.

The merits and seeming defects of the text are so diffuse that a running critique seems to be the only satisfactory manner to fulfill the reviewer's obligation. It so happens that your critic has been concurrently engaged in some of the same Middle and especially Upper Devonian problems dealt with in the report. He is able, therefore, to appreciate the high merit of the work, and at the same time indicate places where caution should possibly be exercised by the casual reader.

The chapter by Frank M. Swartz on the Keyser and Helderberg sequence is an excellent, albeit too brief, summary of the Pennsylvania aspect of the basic work which he and C. K. Swartz have been carrying out in the Appalachian province for many years. Their conclusions and correlations are too well known to make review necessary here. The base of the Helderbergian is still an open question, and likewise the matter of Devonian or Silurian age of the Helderbergian. It is likely that the work of the Swartzes will be the basic determinants when the matters are definitively reviewed. The correlation chart (fig. 17) which the Survey had prepared to accompany this chapter attempts to convey too many relationships for one diagram and is consequently confusing.

The Oriskany sandstone is discussed by Arthur B. Cleaves, whose work on this superficially well-known unit has been most fruitful. Again one wishes for fuller treatment, especially since we have no definitive work on the formation. Apparently the physical relations of the Oriskanian units are fairly well established, but the faunas are not well known, despite the large array of described forms whose names appear on useful faunal charts. A valuable regional survey of the occurrence of the Oriskanian in eastern North America introduces Cleaves' discussion. It is not the reviewer's understanding of Dr. G. A. Cooper's views on the age of the Camden chert of Tennessee that he would now consider it as of Oriskanian age as Dr. Cleaves indicates (p. 95). It would be valuable to have Dr. Cleaves' opinion on the systemic significance of the Oriskanian, especially in view of Dr. Willard's suggestion elsewhere in the volume that geologists should reëxamine the worth of the old idea that the Devonian system in America began both faunally and diastrophically with that formation. It is possible that this chapter over-stresses the importance of Dr. Allen's stimulating, but remote, literature analysis from New Zealand of our Silurian-Devonian boundary problems in terms of the European section. The question might be raised, whether or not the present status of Devonian paleontology the world over warrants the conclusions Dr. Allen draws.

The remainder of the volume summarizes

---

determination on more than six of the 17 fragments, and these might be determined specifically with interrogation. Figure 4 is possibly not molluscan, and is incorrectly interpreted by analytical lines; figures 6 and 7 are problematical; figure 8 is wrongly oriented and erroneously interpreted; figure 14 is too fragmental for identification and shows a most curious reëntrant analytical line at the base; figure 15 appears to be wrongly determined. Fortunately, most other plates appear to be far more carefully compiled and identified than this one.

[2] On Plate 22, which bears the label Middle and Upper Devonian Brachiopoda, we find figures 7, 8 and 9 given to fossils identified as *Syringothyris texta* (Hall) from what are termed "post Chemung" beds at Johnsonburg, Pa. This species is indicative of the Mississippian Keokuk or near equivalents and apparently has never been reported from the Devonian. The specimens illustrated, however, are apparently *Syringothyris angulata* Simpson from the well-known Knapp coquinite at Johnsonburg, of basal Mississippian age. This plate also illustrates the confusion which results from variable magnifications.

the works of Bradford Willard on the Middle and Upper Devonian of Pennsylvania. In presenting the first integrated picture of the Middle Devonian of the state Willard has made his greatest contribution. Most of the well-known stratigraphic units of New York State apparently have been traced into Pennsylvania, as much faunal data would indicate. The embayment environment of the Middle and Upper Devonian accumulation is brought out, and the more clastic aspects of the Pennsylvania development than of the best-known New York Devonian is patent. The presentation has been made with an endeavor to keep the ecologic picture constantly in mind, and particular stress is laid from time to time on the place of each unit in the sedimentary cycle.

The Onondagan stratigraphy of Pennsylvania was not clear before Willard's work. Now the general bearing of the great lime and coralline series in New York State and the eastern interior region to the shoreward clastics of southern and eastern Pennsylvania is shown. The "stillstand" aspect of the Onondagan is stressed. One wishes more data had been presented to support the contention that the Esopus sequence, usually designated Oriskanian, belongs, as Willard says, with the Middle Devonian. Paleontologists will wish for fuller illustration of the critical "Stroudsburgian" faunal elements.

The Hamilton group of Pennsylvania[3] appears to embrace equivalents of all of the well-known New York State Hamilton Units. State survey publications have traditionally shown a weakness for local stratigraphic names, and in this respect the Middle Devonian section of the present volume is as laggard as the usual run. Many new stratigraphic names have been proposed for the Middle Devonian formations in Pennsylvania, the basis for which the evidence in the report itself would seemingly repudiate. Devonian sedimentation continued across state boundaries, and the major classification throughout the embayment area should be uniform.[4] The stratigraphic stickler will also object to the interchangeable and seemingly ill-considered use of the terms group, stage, series, formation, and facies in the Middle and Upper Devonian section of the report. In several places the inseparably entwined physical and biological aspects of a facies are lost sight of. Lithically dissimilar units are said to be "facial equivalents" because of similar faunas, and *vice versa*. The old familiar formational names, Ludlowville, Moscow, Skaneateles, etc., of the New York Hamilton sequence appear only as "facies" names in Pennsylvania. Since no one has yet given us a facies analysis of the New York Hamilton formations, and in view of the well-known facies change of each of the formations from east to west across New York State, it is nearly meaningless to describe, say, a "Moscow facies" in one of the Pennsylvania units. No one knows what a "Moscow facies" is. In most instances the faunal lists offered would strongly suggest the coevality and formational continuity of the Pennsylvania and New York units.

The chapter on the "Portage" (Senecan) of Pennsylvania clarifies the long-standing uncertainty concerning the equivalence of the so-called Portage beds of New York, Pennsylvania and Maryland. The tracing of the Tully limestone equivalents in Pennsylvania has been basic work. Chadwick's clarification of the Portage-Chemung dilemma in New York State is disregarded in working out a nomenclature for Pennsylvania; revision will be necessary. Considerable paleoclimatological emphasis is placed on problematica which are interpreted as "ice markings" on the "Portage" strata of Pennsylvania. One wishes for fuller description or illustration. If the Pennsylvania markings are similar to Clarke's purported

[3] In this report, Willard discontinues his usage of the term Hamilton group as essentially equivalent to Middle Devonian, and reverts to the more customary usage of the term.

[4] An example of what may prove to be duplication of nomenclature is the Stroudsburgian "Stage" of this report. If Willard is correct in his conclusion that the Esopus sequence belongs with the Onondagan and therefore Middle Devonian instead of with the Oriskany and therefore Lower Devonian as most stratigraphers have hitherto supposed, then it would appear to have been clarifying to extend the Ulsterian downward to include the Esopus rather than propose still one more superstructural name. Willard usually refers to his Stroudsburgian as the "Onondaga group" in the text.

ice-markings from the "Portage" of New York it is likely that other interpretations can be as readily entertained. The "Portage" discussion would have been more lucid if some system of facies nomenclature had been employed.

The chapter dealing with the Chautauquan "stage" is one of the shortest and least documented in the volume. Time was not available, apparently, to make the same intimate examination of these upper strata as of the lower ones nearer to Harrisburg. To this lack of personal contact are attributable errors of fact, credit, quotation[5] and seemingly also of interpretation which occur in this section. The philosophy and conclusions are essentially those of the geologists of the Second Survey. While stressing the importance of the progressively southward and westward shift of the focus of origin of Upper Devonian sediments in the embayment, Willard neglects, for reasons not given, the very real evidence of a continuing, albeit diminished, concomitant eastern focus as well. Only by neglecting the eastern thickening and change of facies is it possible to carry the equivalents of the entire Chautauquan series onto the Pocono Plateau as he does. Data adequate to support the correlation are wanting.

Dr. Willard still clings to Stevenson's idea of a great unconformity in southwestern Pennsylvania, which proponents of the idea would have us believe cuts out much of the Chautauquan from that area. The facts available, both faunal and lithic, indicate that no such unconformity exists. Those facts are glossed over. In support of this hypothesis several factual misrepresentations occur, such as the reported thinning to zero of the red beds in the Conemaugh gorge at Johnstown, and the statement that red beds are absent from the Conewango of northwestern Pennsylvania.

In establishing the early Chautauquan shore line across Pennsylvania the author has used the first appearance of *Spirifer disjunctus* in the section as a basic criterion. Ecologically this is a questionable procedure, since it is known that a geographically continuous ecological setting seldom, if ever, existed along the coast of the Upper Devonian sea. Several marine environments were notably deficient in the guide fossil chosen. Several large lobes and deep narrow bays are postulated for the coast line. These may be illusory results due to noncontemporaneity of the first *Spirifer disjunctus* occurrences on two sides of the postulated lobe. It would have been extremely interesting to have had illustrations of dwarf marine faunas which Willard reports from the deep bays. Despite the facieologically questionable procedure, Willard's results may be utterly astute. More detailed evidence is needed, however.

The presentation of the Catskill in Pennsylvania is a worthwhile supplement to Barrell's and Mencher's picture of the "great delta beds." Willard intended to use the term Catskill in the manner approved by custom, now long-standing, as a facies, *i.e.*, magnafacies, rather than as a formational unit. Nevertheless, to the reader's confusion the term is occasionally used in the formational manner of the older reports. In several places the lack of a precise facies terminology leaves the reader fumbling.[6] Willard brings out, as has Mencher, that the red Catskill is apparently a coastal plain deposit, rather than a delta accumulation as reported of old. As Willard was able to bring out through his study of the Green Pond Mountain syncline of New Jersey there is a still more sourceward facies of the Devonian than the Catskill, which is very similar in appearance to the "Pocono." The Devonian or "false Pocono" facies is recog-

[5] Though I. C. White made very great contributions to the stratigraphic knowledge of Pennsylvania through his work on the Second Survey, others, notably J. F. Carll, and F. A. Randall also made fundamental contributions which are not duly considered. The more recent work of Charles Butts, L. C. Glenn and G. H. Chadwick are likewise slighted. While your reviewer receives generous credit, his work is garbled beyond recognition in the reporting. Sections attributed to the reviewer bear little resemblance to his; and he never proposed the strange curtailment of the Chautauquan attributed to him by Willard, nor apparently has anyone else.

[6] *E.g.*, p. 259, in discussing the marine faunas sometimes found in the seaward subfacies of the Catskill magnafacies, Willard says: "Nevertheless, marine incursions are found relatively high in the red beds, and here and there red shale itself may carry salt water invertebrates. These incursions recur intermittently, but are an invaluable means of dating the lower part of the facies."

nized in the Honesdale sandstone of the Pocono Plateau. Apparently the "false Pocono" is ordinarily gradational downward into the Catskill in most areas of Pennsylvania. Considering the embayment scene of Upper Devonian-Catskill deposition, it is strange that the possibility of the south-central Pennsylvania "Pocono" deposits being Devonian in age similar to the "false Pocono" of Green Pond Mountain and Pocono Plateau is not seriously considered. It is disconcerting also to find that while the Honesdale sandstone of the Plateau is recognized as a somewhat higher parvafacies of the "false Pocono" than the Green Pond Mountain occurrence, this upward and westward encroachment of the "false Pocono" magnafacies virtually ceases for Willard with the Honesdale, and that facies and formation (synonymous now!) is identified as continuing for a great distance westward. Some recent students of the facies relationships in northern Pennsylvania have reported data which support the idea that the "false Pocono" facies continues parvafacies after parvafacies on upward across the state through formations which fail by far, due to pre-Pottsville erosion, to reach the Pocono Plateau area. The recrudescence in this respect is not in keeping with the general progressiveness of the report.

Willard restricts the type "Pocono" to the occurrence in the Moosic Mountains, *i.e.*, by recognizing as false "Pocono" the Honesdale sandstone, which caps most of the Pocono Plateau and is demonstrably of Devonian age. The "true Pocono" he says is separated from underlying formations by a slight unconformity, which he correlates with the Knapp (Mississippian) Oswayo (Upper Devonian) unconformity in northwestern Pennsylvania, thus dating the "true Pocono" as Mississippian in age. The lithic data on which this correlation was made are incompletely presented. No faunal data are available for this long correlation as yet. The age of the "true Pocono" is apparently an open question. That at least two "Poconos" occur in the type area is amply demonstrated, however. More data seem to be needed to connect either with the extensive "supposed Pocono" elsewhere.

An elementary discussion of methods introduces the chapter on correlation. It is well to note the large part paleontology has played in Devonian stratigraphic work. Most of the earlier errors were due to neglect of fossil evidence. Not all ecologically-minded stratigraphers will agree with the key idea of this chapter, however (p. 308): "There is but one way to correlate: that is actually to trace a particular bed or group of beds from a given locality to another." It was this procedure which led to the erroneous ideas of Devonian correlation by the "parallelism of strata" school. By so doing, lithology is relied on, facies are interpreted as formations, and we are back where we started. A great many detailed sections about the State make this one of the most valuable chapters of the report. Many more would be most welcome, especially along the northern counties and the Allegheny Front.

In the chapter on geologic history, Dr. Willard lays stress on the importance of the sedimentary cycle in a genetic classification of rocks into systems. He brings out the sedimentary alignment of the Helderbergian sequence of Pennsylvania with the Silurian cycle, and stresses the commencement of the Devonian cycle with the Oriskanian. His analysis of facies relationships in the embayment are generalized but reasonably clear, considering the double use (formational and facieological) he gives most geographic names.

A brief discussion of Devonian orogeny and its bearing on the sedimentary history of the embayment is very lucid, but may leave some queries in the mind of the reader. Why, for example, if the supposed Mississippian Pocono, *i.e.*, "true Pocono," deposits represent the sediments riven from the fresh core of the mountains of Appalachia after their last spasm of the Acadian uplift, do we find that instead of the great off-lap condition we might expect, that in reality we get an on-lap condition of the undoubted basal Mississippian wherever it has been studied in Pennsylvania? Willard's ideas of Catskill origin appear to be a satisfactory fusion of the ideas of Barrell and Raymond, which should be read in conjunction with Mencher's recent analysis of the Catskill in New York state.

The stratigraphic text closes with a philosophical epilogue in which the author pleads

for more uniformitarianism as against what he feels is far too much catastrophist sentiment still abroad. It is refreshing to find Dr. Willard critical of much nonsense which has been written promulgating ideas of "world-wide revolution" at various times in the geologic past, especially between periods. There is good sense in his objection to the time-honored division of the Devonian into a threefold system. As he says, both stratigraphic and faunal evidence point to the reality of only two phases, onlap and off-lap. These are punctuated from place to place by faunal augmentations and losses and occasional recurrent "still-stands," but these do not appear to be of major import. Dr. Willard is opposed to such terms as group, formation, and member (although he uses them), for he says they imply a tendency to "map time not rocks" (*sic*). He seems to feel the need of taking a stand on facies versus formations, but wavers apparently in his devotion. He urges stratigraphers (p. 379) to make mappable facies, not formations, their concern. Should they do this, and the exhortation prevail, then most of the Second Survey work on the Devonian would be quite satisfactory. The recent Devonian hullabaloo supposedly arose from the unsatisfactory nature of that work. Most stratigraphers will agree with Dr. Willard's somewhat contradictory closing epizeuxis, however: "I look forward to the day when our stratigraphically trained geologists will map sedimentary facies as freely and truly as their co-workers, the specialists in igneous and metamorphic phenomena, delineate the multitudinous ramifications of the rocks in their chosen provinces." The stratigraphic geologist is still engaged in historical studies, however, and must be eternally concerned with time and the coeval records of past time. He needs to be able to map and discuss *both* formations and facies in order to fulfill his historic purpose. The present work succeeds eminently when it adheres to this double obligation.

KENNETH E. CASTER

STUDY OF THE PSEUDORTHOCERATIDAE. Rousseau H. Flower, *Palaeontographica Americana*, vol. 2, no. 10, pp. 1–214, pls. 1–9, 1939.

This report is concerned chiefly with an outline of the occurrence of internal shell structures in simple Middle and Late Paleozoic cyrtochoanitic nautiloids and a taxonomic application of the results. Although the nature of the siphuncle has long been employed as a fundamental character in the straight (or slightly curved) cephalopods, other internal structures such as cameral and siphonal deposits have often been regarded as having little or no taxonomic value. In this study, the author demonstrates that internal deposits of several distinct types are common in the Devonian and Carboniferous orthocones, and he concludes that the various types may be used in classification.

The first of the four parts of which the report consists is devoted to the morphology of the pseudorthoceratid shell. It includes discussions of the siphuncle and of the organic deposits found in the phragmacone. Also, attention is called to the occurrence of longitudinal furrows on the inside of the test, and their significance in orienting nautiloids is emphasized. The second part of the study, much of which is highly theoretical, consists of a discussion of the manner in which the various shell elements were secreted. The author believes that the deposits within the camerae served as ballast; they were secreted by individual cameral mantles, which may have been confined to closely related forms with this particular type of calcareous structure. The major portion of the monograph is included in the third part, the systematic paleontology. The Pseudorthoceratidae are divided into 18 genera, which are grouped into three subfamilies, the Pseudorthoceratinae, the Dolorthoceratinae, and the Cayutoceratinae—all three of the subfamilies and 10 of the genera are new. The phylogeny of the family is discussed in the final part of the volume. It is held that the Pseudorthoceratidae evolved from orthochoanitic annulosiphonate nautiloids shortly before the beginning of the Devonian and continued until near the close of the Paleozoic. The preponderance of Devonian over Carboniferous species noted by the author is perhaps to be explained by the fact that the collections available to him came largely from the lower horizon.

The nine quarto plates that accompany

this volume consist of collotype reproductions of photographs. The pictures, many of which are of sections, are much more than ordinarily satisfactory. Also, there are a number of diagrammatic figures and tables in the text which are quite helpful. This report is by far the most comprehensive work on the subject that has been published, and it is also the best of the several major contributions by the author.

A. K. MILLER AND W. M. FURNISH

ILLUSTRATED CARD CATALOGUE OF NORTH AMERICAN DEVONIAN INVERTEBRATES, FIFTH UNIT, GRAPTOLITHINA, compiled by Rudolf Ruedemann: *Wagner Free Institute of Science*, Montgomery Avenue and Seventeenth Street, Philadelphia, Pa.; 13 cards with a total of 39 figures. $0.60, plus about $0.25 for packing and postage.

Copies of the original descriptions and of figures of the type specimens are included on the cards. Ruedemann, in his characteristic terse and adequate manner, has compiled the information on this interesting group of Devonian graptolites. His "observations" in regard to species are particularly apt and illuminating. Though the cards carry the names of five genera and 13 species, the number of graptolites has been reduced to four genera and 12 species through his recent restudy of the type material on which *Monograptus beecheri* was based. Bulman had suggested that this form was not a graptolite, and Ruedemann's study of the type material has shown that the fragments, instead of being a graptolite, are parts of the spinose margin of a trilobite cephalon. After discarding this one genus and species, the four genera and 12 species of Devonian graptolites are as follows:

1. *Chaunograptus gracilis* Clarke
2. *Desmograptus becraftensis* Ruedemann
3. *Desmograptus vandelooi* Ruedemann
4. *Dictyonema cadens* Hall
5. *Dictyonema crassum* Girty
6. *Dictyonema fenestratum* Hall
7. *Dictyonema hamiltoniae*
8. *Dictyonema leroyense* Gurley
9. *Dictyonema megadictyon* Gurley
10. *Dictyonema perradiatum* Gurley
11. *Dictyonema splendens* Billings
12. *Ptiograptus percorrugatus* Ruedemann

Of the four genera listed above, the first may be rather sparsely branched, and the other three are highly branched dendroid forms. As the dendroid forms were dominant in the early appearance of graptolites in the Cambrian, and as they had marked development together with other forms in the Ordovician and Silurian, it is interesting to note that these dendroid types are the only forms known to have lived through into the Devonian. As to location, species 1, 10, and 11 came from Canada, 6 from Mackinac, 12 from Kentucky, and the other seven species from New York.

While commenting on the very few graptolites of the Devonian, it may be stated that the writer is preparing a paper on three species found recently in the Haragan (Lower Devonian) of Oklahoma.

CHARLES E. DECKER

CAMBRIAN MEROSTOMATA, by Gilbert O. Raasch. *Geol. Society of America, Special Paper* No. 19, July, 1939.

Until recently the enigmatic aglaspids were rare fossils of doubtful relationships. Skillful collecting, preparation, and study by Raasch has brought them to the position of an order, with two families, 10 genera, and 21 species. The order, one family, seven genera, and 15 of the species are new. All but one of the species are from the Upper Cambrian; they reach their acme in the Lodi member of the Trempealeau.

The most important discovery is that of a few specimens with part of the appendages. The cephalothorax bears six pairs of uniramous legs, the first chelicerate, thence there can be no question but that these animals are arachnids, the oldest now known.

The trunk consists of 12 articulated segments, the last of which bears a spine, which evidently functioned as a telson. Since the eurypterids and scorpions have 12 segments plus a telson, this raises a question as to the true segmentation in the aglaspids, which can only be decided by finding the location of the anus. If it is beneath the transverse anterior portion of the last segment, then the telson may have originated by the ultimate freeing of the posterior spine. If, however, the anus were beneath the penultimate segment, then these animals had a true telson, but only 11 trunk segments. This latter interpretation, on the present evi-

dence, seems to the reviewer the most probable. The limuloids of the Paleozoic have surprisingly few segments, and disappearance by coalescence at the posterior end may have begun as early as the Cambrian. Raasch, in fact, believes that the telson had been fused to the twelfth segment.

Raasch believes the Aglaspida to have been more nearly allied to the Eurypterida than to any other arachnids, and incidentally, removes *Strabops*, the only supposed Cambrian eurypterid, to the new order. He has, however, introduced a new difficulty into the task of relating the Aglaspida to any other group by finding walking legs like those of the cephalothorax under the first six segments of the trunk of *Aglaspis spinifer*. Since the gills of Eurypterida and Xiphosura are generally supposed to be modified exopodites, an unsupported but fair inference would be that the aglaspid body retained some biramous appendages.

Raasch's paper contains much information not only on the description of the fossils, but on morphology, phylogeny, stratigraphic position, and, in fact, general stratigraphy of the Upper Cambrian. It is a model for monographs of this sort.

PERCY E. RAYMOND

ST. CROIXAN CLASSIFICATION IN MINNESOTA, by C. R. Stauffer, G. M. Schwartz, and G. A. Theil. 17 pp. 2 charts, *Geological Society of America, Bull.*, vol. 50, pp. 1227–1244, 1939, August.

"This paper is presented in an effort to relate the classification of the St. Croixan series that has been inherited by the present Minnesota Geological Survey to those now used elsewhere and especially to adjust it to that commonly called the Conference Classification (Bridge, 1937, p. 234)." This opening sentence of the above paper is a clear expression of the authors' objectives. The reviewer will attempt to evaluate, with the maximum objectivity which his close association with the St. Croixan problem will permit, the extent to which these aims were achieved and will attempt to separate those points of disagreement which are primarily a matter of personal taste and those which seem to violate established facts.

In making a critical evaluation of any proposed local stratigraphic column, the first essential is to find a proper "yardstick" as a standard for comparison. The Minnesota writers have themselves selected the "Conference Classification" of Bridge (1937) for that purpose. In his paper on Cambrian Merostomata (*Geol. Soc. America, Special Paper* 19, *1939*), the reviewer has published a more recent column for the Upper Mississippi Valley, which differs from the "Conference Classification" on a few minor points and contributes considerably greater detail. Since the date of this last publication, the Cambrian Subcommittee of the National Research Council has continued its studies and conferences. Since the Minnesota classification is in some particulars preferable to the "Conference Classification" and vice versa, the writer will attempt, rather, a joint critical comparison of the two, as juxtaposed by the Minnesota writers on page 1238. Beginning at the base of the succession the following comments seem in order.

1. *Regarding the Cedaria zone.*—The Cedaria zone is omitted from the Minnesota section but should be included, as the zone is exposed in northern Chisago County where Atwater and Clement collected *Obolus namouna* (Walcott) in abundance.

2. *Regarding the position of the Galesville member.*—It is now apparent that the Galesville in Minnesota is the lateral equivalent of the Aphelaspis zone. The Galesville is a lateral, barren sand facies of the marine, silty, fossiliferous sandstone to which the term Eau Claire is applied. In the strictest sense, the Galesville is a lateral phase rather than a horizontal stratigraphic unit. This opinion is the result of recently acquired evidence, subsequent to the preparation of both the Minnesota and the Conference columns.

3. *The Taylor Falls-Goodenough discrepancy.*—This particular point is clearly a matter of taste. The Minnesota writers substitute the term Taylors Falls for Goodenough on the basis that at the type locality of the latter the section "is now overgrown and very poorly exposed." The problem of disappearing type localities is a constant irritation, but the policy of changing the names of stratigraphic units on that ac-

count, if persistently carried out, would have chaotic consequence. A further objection is that at Taylors Falls an abnormal shore phase of this unit is represented, and the upper contact is not apparent. The faunal designate *Conaspis* as employed by the Minnesota writers is preferred by the writer to the terms *Eoorthis-Billingsella* of the Conference Classification.

4. *Trempealeau-Jordan-St. Lawrence discrepancies.*—In accordance with the present writer's criteria for distinguishing formations and members (*Kansas Geol. Soc., Ninth Ann. Guidebook, 1935*, p. 303), he is compelled to regard the Madison as a distinct formation rather than a member (in contradistinction to the "Conference" and to the Minnesota writers), and to regard the Trempealeau as one formation (in agreement with the "Conference") and not as two (as proposed by the Minnesota writers). These mutual discrepancies arise as a result of individual policy and all can be accommodated within the scope of the observed facts. The base of the Jordan in Minnesota is at all points a distinct stratigraphic break, marked above by a conglomerate and a distinct fauna. Eastward, in central Wisconsin, the basal Jordan break is not apparent, and for that reason and in line with his defined criteria, the writer regarded the separation as of member rather than of formational value.

In the matter of the Madison, the Minnesota writers themselves are not consistent, since on page 1228 they correlate the Madison of other writers with a part of the Van Oser (a distinct violation of the facts) while on page 1238 they suggest that the Madison is absent. This unit is not absent but overlies the Van Oser division of the Jordan in the southeastern part of the Minnesota and pinches out northwestward.

With respect to the use of the term St. Lawrence, there seems to be precedence for a deplorably varied range of application. On the basis both of (1) current usage by the adjoining States' Surveys, the Federal Survey, and the Cambrian Subcommittee and of (2) strict application to the beds actually occurring at the type locality (St. Lawrence, Minnesota), the writer emphatically prefers to follow the "Conference Classification," which restricts the term St. Lawrence to the beds and faunas constituting the basal fauna of the Trempealeau beneath the Lodi *Dikelocephalus* fauna. The coining of a new term, Nicollet Creek, and the establishing of another type locality for this basal Trempealeau unit cannot but add seriously to the existing confusion of terms and definitions, and such confusion is seriously abetted by the proposed use of the term St. Lawrence in a different sense from that now currently established. It would have been more satisfactory if the Minnesota geologists, as a consequence of their policy of regarding the Trempealeau succession as two rather than a single formation, had coined the new term for the formation, leaving the sequence of member names undisturbed.

With respect to the faunal terminology within the Trempealeau, the writer does not feel that either the Minnesota or the "Conference Classification" is completely satisfactory, nor is any that the writer might, in the present state of knowledge, propose.

5. *Regarding the Cambrian-Keweenawan boundary.*—An extremely interesting assertion by the writers to the effect that "Recent work indicates that the Hinckley sandstone is undoubtedly the equivalent of the Devils Island sandstone of Wisconsin" is particularly gratifying as bearing out a long-standing suspicion of the writer. This brings the Bayfield group into regional proximity with the St. Croixan, and the writers give no evidence (but only the bald statement) of unconformability of Mt. Simon and Hinckley. Similarly there is no published evidence to show that the Devils Island is not the top of the Bayfield group. Thus, it is possible to suggest a descending succession as follows: Mt. Simon—Hinckley (Devils Island)—Chequamagon (Orienta). On the other hand, the Bayfield-Oronto break seems to be extremely prominent and it is the present opinion of the writer that this is the most desirable level at which to draw the Cambrian-Keweenawan boundary.

While it is necessary and natural to emphasize and to evaluate differences, the Minnesota article is in fact more remarkable for the extent to which it brings the local section into general agreement with the regional and national sections. It is important to note that the Minnesota writers

recognize almost exactly the same succession of units and of faunas as does Bridge, the "Conference," and most recent writers. The disparities are mainly with respect to terminology, and most of these can be accommodated with the column shortly to be issued by the Cambrian Subcommittee. In final summary, this writer feels that the only serious points of issue are the different application of the term St. Lawrence and the lack of recognition of a series of beds (Madison formation or member) between the Van Oser Jordan and the Ordovician base.

GILBERT O. RAASCH

O. C. MARSH, PIONEER IN PALEONTOLOGY, by Charles Schuchert and Clara M. Le Vene. 541 pp., 30 pls., 33 figs. Cloth. Price $5.00. Yale University Press, New Haven, Connecticut (1940).

The present work is the 26th published by the Yale University Press through the financial assistance of the Philip Hamilton McMillan Memorial. Paleontologists and geologists in general are thus indebted not only to the authors and to Yale University, but to the donor of this Fund for making available a memoir which should, but probably will not, have wide circulation among all laymen even remotely interested in science; a publication, therefore, which few commercial presses would have cared to issue, for realistically appraised, the hopes of receiving a financial return commensurate with the publication expenses unfortunately are not great.

The story of Marsh is really the tale of the growth of the importance of science in American universities. It is an account of the circumstances which led to his appointment as the first professor of vertebrate paleontology in this country. It is a saga of the 70's and 80's of the past century, the rip-roaring time in American paleontology when Professor Marsh was startling even the unimpressionable scientific world with his incredible discoveries of all sorts of bizarre fossil animals, such as ancestral midget mammals, birds with teeth, flying dragons, and above all, so far as public interest was and is concerned, gigantic dinosaurs. It is a revealing document of Marsh's lifelong feuds with Cope and many others. Thus when the authors tell the story of the "wild and wooly west," during the famous 1874 expedition into the Black Hills, they do not fail to record Marsh's promises to the great Sioux chief, Red Cloud, which led to a housecleaning in the Interior Department and the Indian Bureau, or neglect to mention the reorganization of the United States Geological Survey and of the fight in Congress against Director Powell and his conservation policy, as a result of which Marsh was dropped from the Survey. Nor do the biographers play down Marsh's spending more than a half million dollars (bequeathed him by his philanthropist uncle, George Peabody) in the attempt, almost solely, one gathers, to get ahead of his scientific competitors.

Thus here is a candid story which, as Professor Schuchert states in a letter to a number of his colleagues, frankly relates Marsh's tangled relations with most of his competitors and with his staff. In fact, although the biography is sympathetically written, Marsh, the man, is presented with such objectivity by one who followed him on the Yale staff that not much is added to a stature never considered very great, at least from the personal point of view. Nevertheless, Marsh is correctly portrayed as a dominant man among many strong men in the fields of paleontology and geology. Moreover for twelve long years as the president of the National Academy of Sciences Marsh, in a sense at least, stands out as the leader of all the scientific forces in the New World.

This book, as well as several others, is the result of a labor of love on the part of Professor Schuchert and his able collaborator, Miss Le Vene. The preparation has involved many years of work and the sort of documentation which is ordinarily allotted only to a scientific monograph, for it explores all facets of Marsh's many-sided character. Thus it considers well his ancestry, his boyhood, his education, his rich achievements, and his appalling weaknesses. The very first sentence is typically revealing—"Othniel Charles Marsh had all the physical, mental, and monetary equipment for a successful career." One gets the feeling that Marsh, with all of his rich endowment, would have been a pretty poor specimen indeed if he had not made a success of his life. The im-

pression is equally strong that although he might have wrought better, he might well have been merely a rich man's nephew.

As an example of one of the many advantages which Marsh enjoyed, Schuchert and Le Vene dispassionately point out that in his competition with Cope their subject was especially fortunate in regard to his publication medium, since the *American Journal of Science's* pages were always open to him. Therefore Marsh was able to rush his discoveries into print without more than a few weeks delay. During the four decades covered by his work, the *Journal* published 204 of his papers with a total of approximately a thousand pages. In the year 1872 when the race with Cope for priority was really hot, Marsh had seven papers in the October number of the *Journal* alone. The authors mildly explain what was once a seething issue as follows: "Marsh's habit of doing things at the last possible moment gave the editors and printers of the *Journal* many moments of exasperation. This resulted in an arrangement whereby his papers could appear as an appendix, and thus not disturb the make-up of the rest of the issue."

Schuchert and Le Vene assert that although "Marsh has been charged with being an unscrupulous pirate in matters paleontological—there is abundant evidence in letters at Yale to show that such methods were not confined to either party." This is possibly a more middle-of-the-road statement regarding the Marsh-Cope *cause célèbre* and the "unparalleled public washing of dirty paleontological linen" than can be found in H. F. Osborn's "Cope: Master Naturalist" or in W. B. Scott's "Memoirs of a Paleontologist." Nevertheless all those who are interested in the history of geology and paleontology should read those two volumes along with the present one if they wish to arrive at an undistorted picture of one of the most interesting periods in the history of science, and certainly the most explosive (and, paradoxically, probably the most profitable) in the long evolution of paleontologic thought.

CAREY CRONEIS, Chicago, Illinois

## ĐECORAH OSTRACODA, CORRECTION

G. MARSHALL KAY
Columbia University, New York, N. Y.

Attention is directed to significant errors in the paper on "Ordovician Mohawkian Ostracoda: Lower Trenton Decorah Fauna," published in the Journal, vol. 14, No. 3, pp. 234–269, May, 1940. In the table on pages 236 and 237, the line separating the words "Guttenberg" and "Ion" should be alined with one separating columns 4 and 5 below; localities 5 to 8 are in the Ion member, not in the Guttenberg as the table implies. The ages of the collections are correctly stated in the locality list on page 235, but locality 6 is near Ellsworth, Wisconsin, not Minnesota, as printed in the list and the following table.

H. N. Coryell has directed attention to the erroneous genotype designations of *Eridoconcha* Ulrich and Bassler, 1923, which should be *E. rugosa* Ulrich and Bassler, 1923, Maryland Geol. Survey, Silurian, p. 296, fig. 14 (fig. 9). (Maysville, Cincinnati, Ohio); and of Conchoprimitia Öpik, 1935, which should be *C. gammae* Öpik, 1935, Nat. Soc. Tartu Univ. Annals, vol. 42, p. 4, pl. 1, figs. 3a–c. (Megalaspis limestone, Hundikuristik, Estonia).

The generic name *Saccelatia* is misspelled on page 242.

## NOTICE

The 32nd biennial edition of the Naturalist's Directory was published in September. This Directory comprises the names, addresses and special subjects of interest of naturalists in all parts of North and South America as well as a list of Scientific Periodicals and Natural History Museums. The price is $2.50. The book is published by the Naturalist's Directory, Salem, Mass.

# JOURNAL OF PALEONTOLOGY

## INDEX TO VOLUME 14

### AUTHOR INDEX


| | | No. | Page |
|---|---|---|---|
| 1. | ABERDEEN, ESTHER, Radiolarian fauna of the Caballos formation, Marathon Basin, Texas | (2) | 127 |
| 2. | BRANSON, E. B., and PECK, RAYMOND E., A new cystoid from the Ordovician of Oklahoma | (2) | 89 |
| 3. | CHAO, KING KOO, Upper Paleozoic cephalopods from central Hunan, China | (1) | 68 |
| 4. | CORYELL, H. N., and RIVERO, FRANCES CHARLTON, A Miocene microfauna of Haiti | (4) | 324 |
| 5. | CRONEIS, CAREY, and GEIS, H. L., Microscopic Pelmatozoa: Part 1, Ontogeny of the Blastoidea | (4) | 345 |
| 6. | DURHAM, J. WYATT, *Aturia* in the Upper Miocene of Java | (2) | 160 |
| 7. | EASTON, WILLIAM H., A Pleistocene occurrence of *Libinia dubia*, a brachyuran | (5) | 519 |
| 8. | FLOWER, ROUSSEAU H., The apical end of *Actinoceras* | (5) | 436 |
| 9. | FLOWER, ROUSSEAU H., Some Devonian Actinoceroidea | (5) | 442 |
| 10. | FLOWER, ROUSSEAU H., *Blastocerina*, new name for *Blastoceras* Flower and Castor, not Fitzinger | (5) | 447 |
| 11. | FRITZ, MADELEINE A., *Aparchites canadensis*, a new Devonian ostracode from the Onondaga of Ontario | (1) | 77 |
| | FURNISH, W. M., (See MILLER, A. K.) | | |
| 12. | FURNISH, W. M., and UNKLESBAY, A. G., Diagrammatic representation of ammonoid sutures | (6) | 598 |
| 13. | GARDNER, JULIA, *Nucula camia* Gardner, new name | (3) | 285 |
| | GEIS, H. L. (See CRONEIS, CAREY) | | |
| 14. | GRAVELL, DONALD W., and HANNA, MARCUS A., New larger Foraminifera from the Claiborne of Mississippi | (5) | 412 |
| | HANNA, MARCUS A., (See GRAVELL, DONALD W.) | | |
| 15. | HILLS, JOHN M., Megascopic fossils from the Permian reef trend of West Texas and New Mexico | (2) | 162 |
| 16. | IMLAY, RALBH W,. Upper Jurassic pelecypods from Mexico | (5) | 393 |
| 17. | INGRAM, WILLIAM M., Two new Cypraeas from Costa Rica | (5) | 505 |
| 18. | KAY, G. MARSHALL, Ordovician Mohawkian Ostracoda: Lower Trenton Decorah fauna | (6) | 615 |
| 19. | KING, RALPH H., The gastropod genus *Euphemites* in the Pennsylvanian of Texas | (2) | 150 |
| 20. | KIRK, EDWIN, *Lebetocrinus*, a new crinoid genus from the upper Borden of Indiana | (1) | 74 |
| 21. | LOCHMAN, CHRISTINA, Fauna of the basal Bonneterre dolomite (Upper Cambrian) of southeastern Missouri | (1) | 1 |
| 22. | LOCHMAN CHRISTINA, Corrections to the basal Bonneterre fauna | (5) | 515 |
| 23. | LOEBLICH, ALFRED R., JR., An occurrence of *Isotelus gigas* Dekay in the Arbuckle Mountains, Oklahoma | (2) | 161 |
| 24. | LOEBLICH, ALFRED R., JR., A fine abrasive for use in thin-sectioning | (4) | 378 |
| 25. | MACNEIL, F. STEARNS, Supplementary notes on the occurrence of Tertiary Noetinae | (5) | 507 |
| 26. | MANSFIELD, WENDELL C., Mollusks of the Chickasawhay marl | (3) | 171 |
| 27. | MELLEN, FREDERIC F., Genus *Lituola* in the Adams oil deep test, Lafayette County, Mississippi | (4) | 378 |
| 28. | MILLER, A. K., and FURNISH, W. M., Studies of Carboniferous ammonoids: Parts 1–4 | (4) | 356 |
| 29. | MILLER, A. K., and FURNISH W. M., Studies of Carboniferous ammonoids: Parts 5–7 | (6) | 521 |
| 30. | MOORE, RAYMOND C., Early growth stages of Carboniferous microcrinoids and blastoids | (6) | 572 |
| 31. | NATLAND, M. L., New genus of Foraminifera from the Later Tertiary of California | (6) | 568 |
| 32. | OLSON, EVERETT CLAIRE, Cranial foramina of North American beavers | (5) | 495 |
| 33. | PALMER, KATHERINE V. W., *Anevda*, new name for *Advena* Palmer, 1937, not Gude, 1913 | (3) | 285 |
| | PECK, RAYMOND E., (See BRANSON, E. B.) | | |
| 34. | POPENOE, W. P., California Cretaceous mollusks, correction | (2) | 163 |
| | RIVERO, FRANCES CHARLTON, (See CORYELL, H. N.) | | |
| 35. | SCHENCK, HUBERT G., and THOMPSON, M. L., *Misellina* and *Brevaxina*, New Permian Fusulinid Foraminifera | (6) | 584 |
| 36. | SCOTT, GAYLE, Paleoecological factors of Cretaceous ammonoids | (4) | 299 |
| 37. | SHIMER, H. W., and SHROCK, R. R., Proposed revision of *North American Index Fossils* | (3) | 286 |

| | | No. | Page |
|---|---|---|---|
| | SHROCK, R. R., (See SHIMER, H. W.) | | |
| 38. | SHROCK, R. R., "Lucite" as an aid in studying hard parts of living and fossil animals | (1) | 86 |
| 39. | SOHN, I. G., Check list of Mississippian Ostracoda of North America | (2) | 154 |
| 40. | STAINBROOK, MERRILL A., *Prismatophyllum* in the Cedar Valley beds of Iowa | (3) | 270 |
| 41. | STAUFFER, CLINTON R., Fauna of the Van Oser beds | (1) | 54 |
| 42. | STAUFFER, CLINTON R., Preoccupied specific names of *Arabellites* | (3) | 285 |
| 43. | STAUFFER, CLINTON R., Conodonts from the Devonian and associated clays of Minnesota | (5) | 417 |
| 44. | STERNBERG, C. M., Ceratopsidae from Alberta | (5) | 468 |
| 45. | STERNBERG, C. M., *Thescelosaurus edmontonensis*, n. sp., and classification of the Hypsilophodontidae | (5) | 481 |
| 46. | STERNBERG, R. M., A toothless bird from the Cretaceous of Alberta | (1) | 81 |
| 47. | STUBBS, SIDNEY A., Pliocene mollusks from a well at Sanford, Florida | (5) | 510 |
| 48. | STUMM, ERWIN C., Upper Devonian rugose corals of the Nevada limestone | (1) | 57 |
| 49. | SUTTON, A. H., and WILLIAMS JOHN R., New names for Weches Ostracoda | (2) | 163 |
| 50. | SUTTON, A. H., and WINKLER, VIRGIL D., Mississippian Inadunata-*Eupachycrinus* and related forms | (6) | 544 |
| 51. | TAPPAN, HELEN, Foraminifera from the Grayson formation of northern Texas | (2) | 93 |
| 52. | TEICHERT, CURT, *Helicoprion* in the Permian of western Australia | (2) | 140 |
| 53. | TEICHERT, CURT, Contributions to nautiloid nomenclature | (6) | 590 |
| | THOMPSON, M. L., (See SCHENCK, HUBERT G.) | | |
| 54. | TOULMIN, LYMAN D., Eocene brachiopods from the Salt Mountain limestone of Alabama | (3) | 227 |
| 55. | TROMP, S. W., The value of quantitative date in microstratigraphy | (4) | 379 |
| 56. | TURNER, F. E., *Alsataspis bakeri*, a new Lower Ordovician trilobite | (5) | 516 |
| 57. | TURNER, F. E., *Cantharus bentsonae*, new name for *Cantharus cowlitzensis* Turner | (5) | 518 |
| | UNKLESBAY, A. G., (See FURNISH, W. M.) | | |
| 58. | USINGER, ROBERT L., Fossil Lygaeidae (Hemiptera) from Florissant | (1) | 79 |
| 59. | WELLS, JOHN W., *Sphaerospongia* in the Tully formation | (5) | 502 |
| 60. | WETMORE, ALEXANDER, Avian remains from the Pleistocene of central Java | (5) | 447 |
| 61. | WHITE, THEODORE E., Holotype of *Plesiosaurus longirostris* Blake and classification of the plesiosaurs | (5) | 451 |
| | WILLIAMS, JOHN R., (See SUTTON, A. H.) | | |
| | WINKLER, VIRGIL D., (See SUTTON, A. H.) | | |


## SUBJECT INDEX


Abrasive: Thin-sectioning (24).
*Actinoceras:* Morphology (8).
Actinoceroidea: Devonian (9).
*Advena:* Mollusk *Anevda* (33).
Alabama: Eocene brachiopods (54).
Alberta: Cretaceous toothless bird (44); Ceratopsidae (45).
*Alsatopsis bakeri:* Ordovician trilobite (56).
Ammonoids: Sutures (12); Carboniferous (28) (29); Cretaceous paleoecology (36).
*Anevda:* Mollusk *Advena* (33).
*Aparchites canadensis:* Ontario Devonian ostracode (11).
*Arabellites:* Devonian Polychaeta (42).
Arbuckle Mountains: Ordovician trilobite *Isotelus gigas* (23)
*Aturia:* Java Miocene cephalopod (6).
Australia: Permian *Helicoprion* (52).
Beavers: North American (32).
Birds: Java Pleistocene (60); Alberta cretaceous (44).
*Blastoceras: Blastocerina:* (10).
*Blastocerina: Blastoceras* (10).
Blastoidea: Pelmatozoa (5).
Blastoids: Carboniferous (30).
Bonneterre fauna: Missouri Upper Cambrian (21).
Borden: Indiana Mississippian crinoid *Lebetocrinus* (20).
Brachiopods: Alabama Eocene (54).
Brachyuran: Pleistocene *Libinia dubia* (7).
*Brevaxina:* Permian Fusulinid (35).
California: Later Tertiary Foraminifera (31); Cretaceous mollusks (34).
Cambrian fauna: Missouri Bonneterre (21); Van Oser (41).
*Cantharus: C. bentsonae, C. cowlitzensis* (57).
Carboniferous: Ammonoids (28) (29); microcrinoids, blastoids (30).

Cephalopods: China Upper Paleozoic (3); *Aturia*, Java Miocene (6).
Ceratopsidae: Alberta (45).
Chickasawhay marl: Tertiary mollusks (26).
China: Upper Paleozoic, cephalopods (3).
Claiborne: Mississippi Foraminifera (14).
Conodonts: Minnesota Devonian (43).
Corals: Iowa Devonian *Prismatophylum* (40); Nevada limestone, Devonian (48).
Costa Rica: Cypraeas (17).
Cretaceous: California mollusks (34); ammonoid paleoecology (36); Alberta toothless bird (44); Dinosaur, *Hypsilophodontidae* (46).
Crinoids: Indiana Mississippian *Lebetocrinus* (20); Mississippian *Eupachycrinus* (50).
Cypraeas: Costa Rica (17).
Cystoid: Oklahoma Ordovician (2).
Decorah fauna: Ordovician (18).
Devonian: Radiolarian (Texas (1); Actinoceroidea (9); Ontario ostracode *Aparchites canadensis* (11); Iowa *Prismatophyllum* (40); Minnesota conodonts (43); Polychaeta *Arabellites* (42); Nevada limestone corals (48); *Sphaerospongia*, sponge (59).
Eocene: Alabama brachiopods (54).
*Eupachycrinus:* Mississippian crinoids (50).
*Euphemites:* Texas Pennsylvanian gastropod (19).
Florida: Pliocene mollusks (47).
Florissant: Miocene Lygaeidae (Hemiptera) (58).
Foraminifera: Mississippi, Claiborne (14); Mississippi *Lituola* (27); Later Tertiary, California (31); Texas Tertiary, Grayson (51).
Fusulinids: Permian *Misellina, Brevaxina* (35).
Gastropod: Texas Pennsylvanian *Euphemites* (19).
Grayson formation: Texas Tertiary Foraminifera (51).
Haiti: Miocene microfauna (4).
*Helicoprion:* Australia Permian (52).
Hypsilophodontidae: Cretaceous dinosaur (45).
Index fossils: North America (37).
Indiana: Mississippian crinoid *Lebetocrinus* (20).
Iowa: Devonian coral: *Prismatophyllum* (40).
*Isotelus gigas:* Oklahoma Ordovician trilobite (23).
Java: Miocene cephalopod *Aturia* (6); Pleistocene birds (60).
Jurassic: Mexico, pelecypods (16).
*Lebetocrinus:* Indiana Mississippian crinoid (20).
*Libinia dubia:* Pleistocene brachyuran (7).
*Lituola:* Mississippi Foraminifera (27).
"Lucite": Paleontological technique (38).
Lygaeidae (Hemiptera): Miocene Florissant (58).
Mexico: Jurassic pelecypods (16).
Microcrinoids: Carboniferous (30).
Microfauna: Haiti Miocene (4).
Microstratigraphy: Quantitative data (55).
Minnesota: Devonian conodonts (43).
Miocene: Haiti microfauna (4); Java cephalopod *Aturia* (6); Florissant Lygaeidae (Hemiptera) (58).
*Misellina:* Permian Fusulinid (35).
Mississippi: Claiborne Foraminifera (14); Foraminifera *Lituola* (27).
Mississippian: Indiana crinoid *Lebetocrinus* (20); North America, Ostracoda (39); crinoid *Eupachycrinus* (50).
Missouri: Upper Cambrian Bonneterre fauna (21).
Mollusks: Chickasawhay marl Tertiary (26); *Advena, Anevda* (33); California Cretaceous (34); Florida Pliocene (47).
Morphology: *Actinoceras* (8).
Nautiloid: Nomenclature (53).
Nevada Limestone: Devonian corals (48).
New Mexico: Permian fauna (15).
Noetinae: Tertiary pelecypod (25).
Nomenclature: Nautiloid (53).
North America: Beavers (32); index fossils (37); Mississippian Ostracoda (39).
*Nucula camia:* Pelecypod (13).
Oklahoma: Ordovician cystoid (2); Ordovician trilobite *Isotelus gigas* (23).
Ontario: Devonian ostracode *Aparchites canadensis* (11).
Ordovician: Oklahoma cystoid (2); Decorah fauna (18); Oklahoma trilobite *Isotelus gigas* (23). Trilobite *Alsataspis bakeri* (56).
Ostracoda: Ontario Devonian, *Aparchites canadensis* (11), North America Mississippian (39); Weches (49).

Paleoecology: Cretaceous ammonoids (36).
Paleontological technique: "Lucite" (38).
Pelecypods: *Nucula camia* (13); Mexico Jurassic (16); Tertiary Noetinae (25).
Pelmatozoa: Blastoidea (5).
Pennsylvanian: Texas gastropod *Euphemites* (19).
Permian: Fusulinid *Misellina, Brevaxina* (35); Australia *Helicoprion* (52).
Permian fauna: West Texas, New Mexico (15).
Pleistocene: *Libinia dubia*, brachyuran (7); Java birds (60).
Plesiosaur classification: (61).
*Plesiosaurus longirostris:* (61).
Pliocene: Florida mollusks (47).
Polychaeta: Devonian *Arabellites* (42).
*Prismatophyllum:* Iowa Devonian coral (40).
Quantitative data: Microstratigraphy (55).
Radiolaria: Texas Devonian (1).
*Sphaerospongia:* Tully formation, Devonian (59).
Sponge: *Sphaerospongia*, Tully formation (59).
Tertiary: Pelecypod Noetinae (25); Chickasawhay marl mollusks (26); California Foraminifera, Later Tertiary (31); Texas Grayson Foraminifera (51).
Texas: Devonian Radiolaria (1); Permian Fauna New Mexico (15); Pennsylvanian gastropod *Euphemites* (19); Tertiary Grayson Foraminifera (51).
*Thescelosaurus edmontonensis:* Cretaceous dinosaur (46).
Thin-sectioning: Abrasive (24).
Toothless bird: Alberta Cretaceous (44).
Trilobite: Oklahoma Ordovician *Isotelus gigas* (23); Ordovician *Alsataspis bakeri* (56).
Tully formation: *Sphaerospongia* (59).
Upper Paleozoic: China cephalopods (3).
Van Oser fauna: Cambrian (41).
Weches Formation: Ostracoda (49).
West Texas: Permian fauna (15).

*An A. A. P. G. book* *Recommended!*

# MIOCENE STRATIGRAPHY OF CALIFORNIA

## By ROBERT M. KLEINPELL

This Work Establishes a Standard Chronologic-Biostratigraphic Section for the Miocene of California and Compares It with the Typical Stratigraphic Sequence of the Tertiary of Europe

---

WHAT OTHERS HAVE WRITTEN ABOUT IT

"In spite of any defects it may have, moreover, many of us suspect that Kleinpell's book is of the kind called epoch-making. If so, in 50 or 100 years it will stand out like a beacon among its contemporaries and, along with a very few others of them will read with a 'modern' tang. Oppel's 'Die Juraformation,' or Suess' 'Die Entstehung der Alpen,' or to go back to the beginning, De Saussure's 'Les Voyages dans les Alpes' may be cited among older geological classics that are now distinguished by this same tang."—Ralph D. Reed in *Journal of Paleontology,* Vol. 13, No. 6 (November, 1939), p. 625.

"The Neogene of California is disposed in tectonic basins, about a dozen in number, from Humboldt in the north to Los Angeles in the south. About half-way along is the Paso Robles basin, and in this lies the Reliz Canyon, which provides the author with his type section. The aerial photograph serving as frontispiece shows the area to be sufficiently arid to give a practically continuous exposure; but one must admire the painstaking determination with which so many successive associations of Foraminifera were collected, identified and tabulated. Such labour would scarcely have been thought of without the stimulus which the search for oil has given to the detailed study of Foraminifera.

"This should be the standard work on the Miocene of California for years to come."
A.M.D. in *Nature,* Vol. 144 (London, December 23, 1939), p. 1030.

---

- 450 pages.
- 14 line drawings, including correlation chart in pocket.
- 22 full-tone plates of Foraminifera.
- 18 tables (check lists and range chart of 15 pages).
- Bound in blue cloth; gold stamped; paper jacket; 6x9 inches.

*PRICE: $5.00, POSTPAID*

*($4.50 TO A.A.P.G. MEMBERS AND ASSOCIATE MEMBERS, LIBRARIES, AND COLLEGES)*

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA, OKLAHOMA, U.S.A.

**Verlag von Gebrüder Borntraeger in Berlin W 35 Deutschland**

**Fortschritte der Paläontologie.** prepared under direction of O. H. Schindewolf, Berlin, with aid of numerous specialists. Vol. 1—Review of the years 1935-1936, contains 384 pp., 2 figs. Price, RM 29.60; Vol. 2—Review of the years 1937-1938, contains 402 pp. Price, RM 31.20.

***Fortschritte der Paläontologie*** **is intended to be a biennial publication indicating significant advances in paleozoology and paleobotany by means of critical summaries and discussion of the most important works issued in successive two-year periods. The first two volumes, now available, cover literature of 1935 to 1938, and provide a comprehensive view of the present status of paleontological research.**

**Paläontologie,** Entwicklungs- und Vererbungslehre (Paleontology, Evolutionism and Genetics) by O. H. Schindewolf; contains 108 pages, 34 text figures; published 1936. Price, RM 5.20.

**This volume develops from paleontological observations and theoretical considerations a new orientation of studies on evolution. Critical inquiry on questions of evolutionary factors and a refutation of Lamarckian theories leads to accommodation of previously divergent views on evolution and heredity.**

**Detailed descriptions and prospectuses free**

## BACK VOLUMES AT HALF PRICE

Members and associate members of the Society of Economic Paleontologists and Mineralogists and of the Paleontological Society and subscribers of the

## JOURNAL OF PALEONTOLOGY

will be privileged for a limited time to purchase complete Volumes 2 (1928) to 11 (1937) at the very special price of Three Dollars ($3.00) per volume. This offer represents a 50 per cent discount from regular prices and gives opportunity that should not be overlooked. Furthermore, only part of the supply of back volumes will be sold at this price. The stock of Volume 1 is exhausted, but any others can be purchased. Place order promptly if you wish to secure discount because this offer will be withdrawn as soon as allotment of copies is exhausted.

Members and associate members of the Society of Economic Paleontologists and Mineralogists and subscribers of the

## JOURNAL OF SEDIMENTARY PETROLOGY

may purchase, for a limited time, complete Volumes 1 (1931) to 7 (1937), at half price, One Dollar and a Half ($1.50) per volume.

**SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS**
**Box 979, Tulsa, Oklahoma**

# OFFICERS OF THE SOCIETIES

## SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

*For the year ending April, 1941*

*President*, CAREY CRONEIS, Chicago, Ill.

*Vice-President*, JOHN R. SANDIDGE, San Antonio, Texas.

*Past-President*, GAYLE SCOTT, Fort Worth, Texas.

*Past-President*, E. H. SELLARDS, Austin, Texas.

*Secretary-Treasurer*, HENRYK B. STENZEL, Austin, Texas.

## THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

*For the year ending April, 1941*

*President*, L. C. SNIDER, New York City.

*Past-President*, HENRY A. LEY, San Antonio, Texas.

*Vice-President*, JOHN M. VETTER, Houston, Texas.

*Secretary-Treasurer*, ED. W. OWEN, San Antonio, Texas.

*Editor*, W. A. VER WIEBE, Wichita, Kansas.

*Society Headquarters*, 608 Wright Bldg., Tulsa, Okla.

## PALEONTOLOGICAL SOCIETY

*For the year ending December, 1940*

*President*, C. O. DUNBAR, New Haven, Conn.

*Vice-President*, P. S. WARREN, Edmonton, Alberta.

*Secretary*, H. E. VOKES, New York, N.Y.

*Treasurer*, ROBERT R. SHROCK, Cambridge, Mass.

*Editor*, C. WYTHE COOKE, Washington, D.C.

*Councilors*

R. W. CHANEY, Berkeley, Calif.

C. W. GILMORE, Washington, D.C.

J. A. CUSHMAN, Sharon, Mass.

U. S. GRANT IV, Los Angeles, Calif.

## GEOLOGICAL SOCIETY OF AMERICA

*For the year ending December, 1940*

*President*, ELIOT BLACKWELDER, Stanford University, Calif.

*Past-President*, T. WAYLAND VAUGHAN, Washington, D.C.

*Vice-President*, DOUGLAS JOHNSON, New York, N.Y.

*Vice-President*, E. L. BRUCE, Kingston, Ont.

*Vice-President*, RALPH W. CHANEY, Berkeley, Calif.

*Vice-President*, M. N. SHORT, Tucson, Ariz.

*Secretary*, C. P. BERKEY, New York, N.Y.

*Treasurer*, E. B. MATHEWS, Baltimore, Md.

*Society Headquarters*, 419 West 117th St., New York, N.Y.